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MIDDLE PENNSYLVANIAN (ATOKAN) CRINOIDS FROM OKLAHOMA AND MISSOURI[1]

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ABSTRACT

Crinoids described in this study are divided among three subclasses, Flexibilia, Inadunata, and Camerata. The Flexibilia are represented by one species ascribed to *Synerocrinus farishi* Laudon. The Inadunata are represented by two orders, the Disparida and the Cladida; the former, divided between two families, is represented in turn by two species, *Isoallagecrinus barnettensis,* n. sp., and *Synbathocrinus* sp. cf. *S. melba* Strimple. The Cladida contain 26 species divided among 12 families; 10 of these species are new: *Atrapocrinus mutatus* (type species of *Atrapocrinus,* new genus), *Anchicrinus echinosacculus, Brabeocrinus primus, Moundocrinus coalensis, Paracromyocrinus planatus, Clathrocrinus grileyi, Affinocrinus orbis, Platyfundocrinus webbersensis, Sciadiocrinus plautus,* and *Proallosocrinus exemptus.* Seven forms, mostly based on individual ossicles, are assigned to genera but not to species. Ten previously described species are included. Camerate crinoids are represented by two new species, *Planacrocrinus knappi* and *Globacrocrinus centronodus,* both of the family Acrocrinidae.

Most of the specimens were collected in Coal County, but a few were obtained in Love, Carter, Johnston, and Wagoner Counties, Oklahoma. Specimens from the Burgner Formation were found in Jasper County, Missouri. All are from the Atokan Stage.

Superfamily Decadocrinacea Bather is proposed for reception of Decadocrinidae and Clathrocrinidae. The genus *Appalachiacrinus* Burke, 1974, is here referred to *Laudonocrinus* Moore & Plummer, 1940, as a junior subjective synonym.

INTRODUCTION

The primary purpose of this study is to record and describe a crinoid fauna of Atokan age from two localities in Coal County, Oklahoma. A few species from the Burgner Formation of Jasper County, Missouri, not reported by Knapp (1969), are included. One new species from the Webbers Falls Shale Member, Atoka Formation, in Wagoner County, Oklahoma, is described and material is included from an unnamed shale in Johnston County as well as from the Bostwick Conglomerate in Carter County, Oklahoma. Some of the material consists of spinose first primibrachs of the arms, which have distinctive configuration and surface ornamentation. Generic assignment of the axillary primibrachs was attempted primarily on the basis of those characters and no effort was made toward speciation. It is my considered opinion that careful observation of

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all characters, including morphology of the articulating surfaces, could lead to use of such ossicles as stratigraphic tools.

Of the 25 genera involved, 14 are also known from Morrowan or older rocks and 20 are also known from Desmoinesian or younger rocks (Table 1). Closest affinities appear to be with

TABLE 1.—*Tabulation of Genera of Atokan Age from Oklahoma and Missouri That Also Occur in Morrowan or Desmoinesian Strata.*

GENERA	Morrowan	ATOKAN	Desmoinesian
Affinocrinus	X	X	–
Alcimocrinus	X	X	–
Anchicrinus	X	X	X
Anobasicrinus	X	X	X
Atrapocrinus	–	X	–
Brabeocrinus	–	X	X
Clathrocrinus	–	X	?[1]
Diphuicrinus	X	X	X
Elibatocrinus	–	X	X
Globacrocrinus	X	X	X
Graffhamicrinus	–	X	X
Isoallagecrinus	X[2]	X	X
Metacromyocrinus	X	X	X
Microcarinocrinus	–	X	X
Mooreocrinus	?[3]	X	X
Moundocrinus	–	X	?[1]
Oklahomacrinus	–	X	X
Paracromyocrinus	X	X	X
Planacrocrinus	X	X	?[1]
Platyfundocrinus	–	X	–
Proallosocrinus	X	X	–
Protencrinus	–	X	X
Sciadiocrinus	X	X	X
Synbathocrinus	–[4]	X	?[1]
Synerocrinus	–	X	X

[1] Occurs above Desmoinesian.
[2] Forms reported to be young *Allocatillocrinus*.
[3] Forms reported as *Cromyocrinus*.
[4] Occurs below Morrowan.

stratigraphically younger crinoid faunas, but not overwhelmingly so. On the specific level only one species, *Graffhamicrinus antiquus,* is also known to occur in the Atokan crinoid fauna reported by Strimple and Watkins (1969) from the Llano Uplift in northcentral Texas. Most of the Atokan crinoids described by Strimple and Watkins (*ibid.*) were from the Lemons Bluff Limestone of San Saba County, Texas, and are thought to be younger than *G. antiquus,* which is typically found in the Soldiers Hole Member, Big Saline Formation (Atokan) of Mason County, Texas. In Oklahoma *G. antiquus* is found in the Bostwick Conglomerate, Lake Murray Formation (Atokan), in the Ardmore Basin. There appear to be no really close ties between the Atokan crinoids of Oklahoma, Missouri, or Texas, indicating that they represent isolated provinces.

For the purpose of inclusion in Part T (Echinodermata 2), *Treatise on Invertebrate Paleontology,* the genus *Appalachiacrinus* Burke, 1974, is considered here. *A. erwini* Burke, 1974, type species of the genus, is a young specimen and shows more tumidity of cup plates than is typical of *Laudonocrinus*; however, young specimens of *L. subsinuatus* (Miller & Gurley) figured by Strimple & Moore (1971a, pl. 9, fig. 1a,b and 3) also demonstrate some plate tumidity. The primibrachs *1* of *A. erwini* are proportionately shorter than those found in young specimens of *L. subsinuatus,* but this is not considered to be of generic stature. The basal concavity of *A. erwini* is no more pronounced than that found in one syntype of *L. subsinuatus.* There does not seem to be any real justification for the genus *Appalachiacrinus,* which is assigned herein as a junior subjective synonym of *Laudonocrinus* Moore & Plummer, 1940. *Appalachiacrinus erwini* is designated *Laudonocrinus erwini* (Burke), new combination.

ACKNOWLEDGMENTS

Materials from Oklahoma used in this study were collected by Allen A. Graffham, Maxim K. Elias, Christina Strimple, the late E. J. Palmer, Claude Spinosa, Walter Nassichuk, and Amel Priest. C. B. Branson, formerly Director of the Oklahoma Geological Survey, made the bulk of the specimens from Oklahoma available for study. Specimens from the Burgner Formation of Missouri used were in collections on loan from the National Museum of Natural History and the University of Missouri, which were observed but not reported on by W. D. Knapp, while a graduate student at The University of Iowa. The specimens from Missouri were collected by the late E. J. Palmer. Publication of this paper was made possible by a contribution from the University of Kansas Endowment Association, covering part of the printing costs.

SYSTEMATIC PALEONTOLOGY

Subclass FLEXIBILIA Zittel, 1895

Order TAXOCRINIDA Springer, 1913

Superfamily TAXOCRINACEA Angelin, 1878

Family SYNEROCRINIDAE Jaekel, 1918

Genus SYNEROCRINUS Jaekel, 1897

SYNEROCRINUS FARISHI Laudon, 1937

Figure 1,*3*

Synerocrinus farishi Laudon, 1937, p. 706-707, text-fig. 2.
Talanterocrinus farishi (Laudon), Moore & Plummer, 1940, p. 71, 97.
Talanterocrinus farishi (Laudon), Bassler & Moodey, 1943, p. 698.
Synerocrinus farishi Laudon, Strimple & Watkins, 1969, p. 224-225.

Remarks.—As discussed by Strimple and Watkins (1969, p. 224), the generic designation for this species is in some question because the posterior side of the cup is unknown. The monotype of the species is from the Bostwick Conglomerate (Atokan) of Love County, Oklahoma. A large specimen from the Atoka Formation of Coal County, Oklahoma, which is also lacking the base of the cup, is assigned to the species.

Hypotype.—OU 4480, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center SW ¼ NE ¼ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Subclass INADUNATA Wachsmuth & Springer, 1885

Order DISPARIDA Moore & Laudon, 1943

Superfamily ALLAGECRINACEA Carpenter & Etheridge, 1881

Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

Genus ISOALLAGECRINUS Strimple, 1966

ISOALLAGECRINUS BARNETTENSIS Strimple, new species

Figure 2

Description.—Crown compact, subcylindrical, surface marked by numerous, pronounced granulations, arms comprising about 0.8 total height of crown. Dorsal cup bowl-shaped, distal tips of basals extending to 0.2 total height of cup in holotype (OU 7138). Radials very large, protruded in midportions, parallel to length, and overhanging basals. Two arms (*C* and *E* rays) have well-rounded exteriors, and are considerably larger than all other arms; small arms have planate exteriors. In the single arms of *C* and *D* rays the second brachial is almost 10 times as long as the first brachial and the third brachial is 2.5 times as long as the first brachial. Arms in all other rays narrow and comprised of shorter brachials except for primibrach *1*, which has the same length in all rays. Two arms present in both *A* and *B* rays, with *D* ray unobserved.

The stem is rather large and round; proximal columnals are thin and taper rapidly for a short distance, thereafter stabilizing in size and becoming thicker. Sections of the column are attached to all three type specimens.

Measurements of Holotype in Millimeters.—Crown length 11.4, cup height 2.0, width 3.9.

Discussion.—only one other species of the genus is known from Atokan strata, *Isoallagecrinus erectus* Strimple & Watkins (1969, p. 217). *I. erectus* lacks the pronounced transverse tumidity of radials and the spectacular ornamentation found in *I. barnetti*. *I. erectus* also has proportionately longer arms.

Types.—Holotype OU 7138, paratypes OU 7139, OU 7140, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center SW ¼ NE ¼ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily BELEMNOCRINACEA S. A. Miller, 1883

Family SYNBATHOCRINIDAE S. A. Miller, 1889

Genus SYNBATHOCRINUS Phillips, 1836

SYNBATHOCRINUS sp. cf. S. MELBA Strimple, 1938

Figure 1,*1,2*

cf. *Synbathocrinus melba* Strimple, 1938, p. 8, pl. 1, fig. 12, 13.

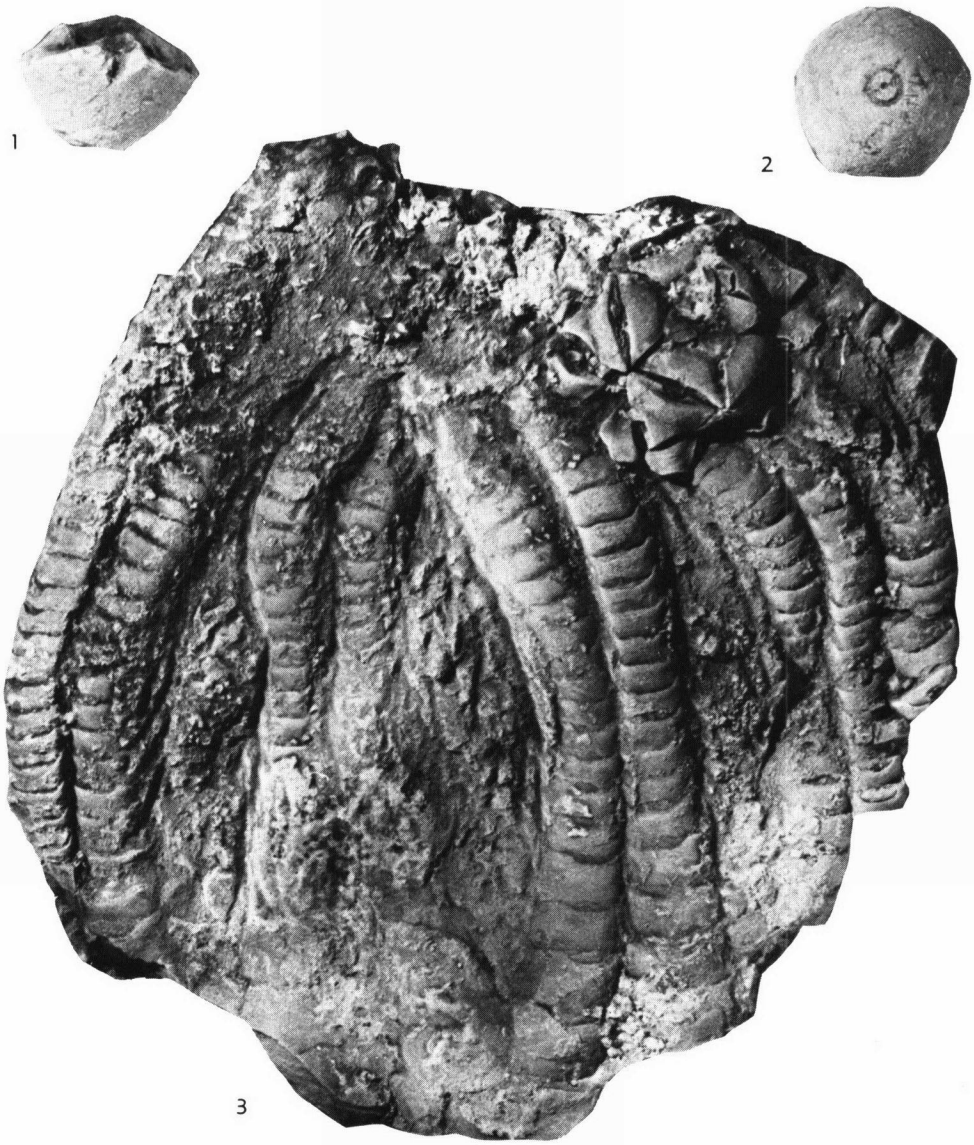

FIG. 1. *Synbathocrinus (1, 2)* and *Synerocrinus (3)* from Oklahoma and Missouri.——*1, 2. Synbathocrinus* sp. cf. *S. melba* Strimple, hypotype USNM 144997, from Burgner Formation, Missouri; cup viewed from posterior and base, ×4. ——*3. Synerocrinus farishi* Laudon from Atoka Formation, Oklahoma; hypotype OU 4480a, crown viewed from side with partial crown OU 4480b of *Oklahomacrinus frostae* Strimple & Watkins shown in upper right, ×1.5.

Description.—Dorsal cup small, subconical; basals three, readily visible in side view; radials five, large, left distal corner of *C* radial truncated and, to a lesser degree, right distal corner of *D* radial, forming an anal notch in *CD* interray. Cup 3.7 mm high, 5.5 mm wide.

Discussion.—The holotype and one hypotype of *Synbathocrinus melba* have been reported from Missourian rocks of northeastern Oklahoma. The present specimen, from Atokan rocks of Missouri, was discussed in Strimple, Allison, and Kline (1971, p. 13) in comparison with *S. alaskaensis* described by those authors, which species is from Atokan? strata in Alaska. *S. alaskaensis* has bulbous radials that overhang the basals. *S. melba* has a more evenly expanded cup and radials lack convexity.

Hypotype.—USNM 144997, reposited National Museum of Natural History, Washington, D.C.; collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); mine dump, SE ¼ sec. 20, T. 28 N., R. 32 W., 1.5 miles south of Centerville, Jasper County, Missouri.

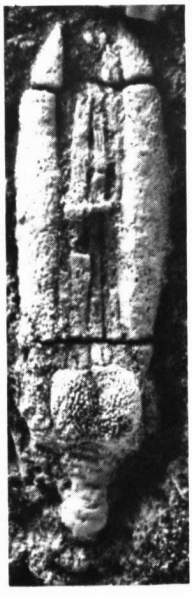

FIG. 2. *Isoallagecrinus barnettensis* Strimple, n. sp., from Atoka Formation, Coal County, Oklahoma; side view of holotype crown, OU 7138, ×5.

Order CLADIDA Moore & Laudon, 1943

Suborder POTERIOCRININA Jaekel, 1918

Superfamily SCYTALOCRINACEA Moore & Laudon, 1943

Family SCYTALOCRINIDAE Moore & Laudon, 1943

Genus ATRAPOCRINUS Strimple, new genus

Type Species.—Atrapocrinus mutatus Strimple, n. sp.

Diagnosis.—Crown cylinder-shaped; dorsal cup low cone-shaped with flat or mildly convex base; infrabasals not preserved, but proximal ends of five moderately large basals curved slightly inward indicating a subhorizontal infrabasal circlet; five large radials; one narrow anal plate. Primibrach *1* axillary in all rays; 10 arms cuneate, long and slender.

Discussion.—Atrapocrinus is apparently related to the Scytalocrinidae, although considerably more advanced than typical members of the family. The Morrowan genus *Morrowcrinus* Moore & Plummer, 1938, retains three anal plates; however, the posterior interradius is restricted and the plates are narrow, indicating change that very likely led to reduction in the number of plates. *Scytalocrinus aftonensis* Strimple, 1951, from the Fayetteville Formation (Chesterian) demonstrates a change in structure of the base of the cup wherein the infrabasals extend horizontally from the columnar attachment area with only distal ends directed upward. *Atrapocrinus mutatus* has eliminated two anal plates from the dorsal cup and has very large primibrachs *1* as found in *Morrowcrinus,* but the secundibrachs are smaller and more like those of *Scytalocrinus aftonensis* than of typical *Morrowcrinus.*

Occurrence.—Atokan Stage (Pennsylvanian); Oklahoma.

ATRAPOCRINUS MUTATUS Strimple, new species

Figure 3,*1-5*

Diagnosis.—Characters of genus.

Discussion.—Primibrach *1* is as large as the radial plate. Secundibrachs are somewhat elongated and the pinnular-bearing side of each is not only longer but also protrudes laterally like a small spur. In side view of the arms the "spur" is seen to be a distal extension of the facet for

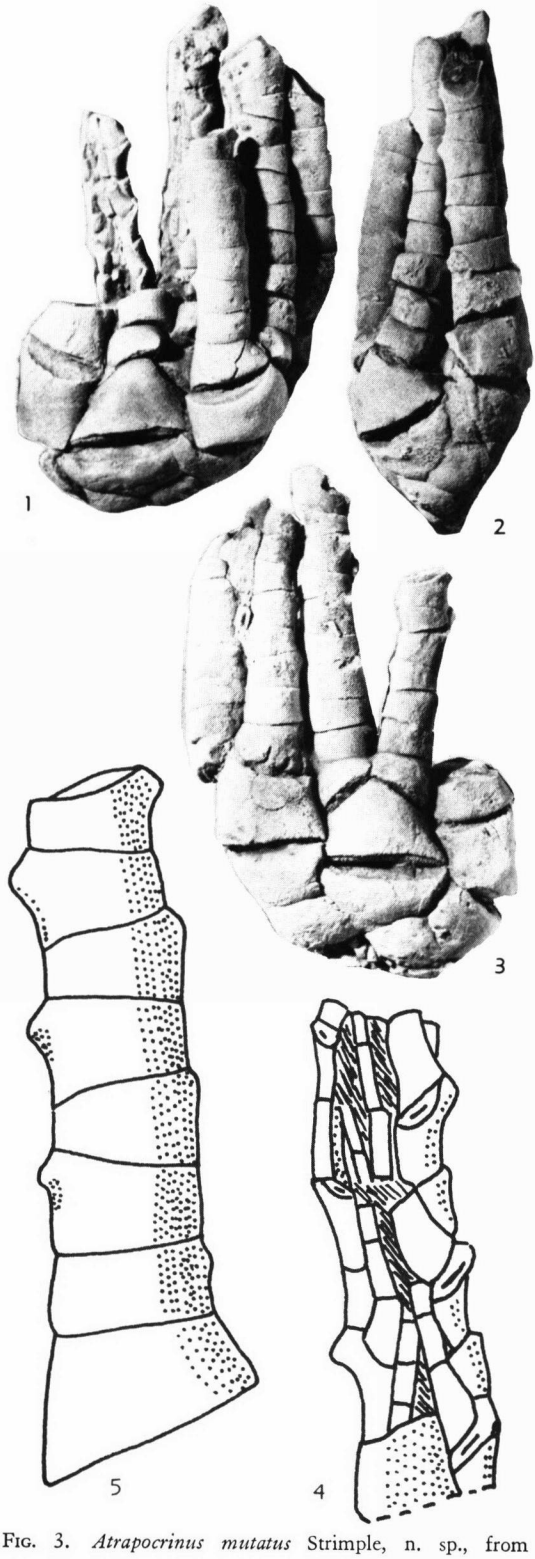

FIG. 3. *Atrapocrinus mutatus* Strimple, n. sp., from Atoka Formation, Oklahoma.——*1-3*. Holotype crown (OU 6076) from *E* ray, *CD* interray, and *B* ray, ×2.5. ——*4, 5*. Camera lucida drawings of inner side of one arm and exterior side of another arm as shown in figure *1*, ×6.

the reception of the pinnule. These elements are very wide at their base.

Primibrachs *1* are axillary and differ somewhat in length with *B* and *D* shortest, *C, E* slightly longer and equidimensional, and *A* the longest. Secundibrachs are cuneiform, slightly wider than long, have well-rounded exteriors, and each long side has a lateral extension with the appearance of a short, rounded spine near the distal end. The lateral extension is functional rather than ornamental in being the support for the pinnular attachment facet. First pinnulars are very large and all have flattened exteriors.

Measurements of Holotype in Millimeters.—Length of crown (incomplete) 28.0; height of cup (distorted) 5.5, width (distorted) 16.4.

Holotype.—OU 6076, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); Coal County, Oklahoma; NE ¼ SW ¼ sec. 23, T. 1 N., R. 8 E.

Family BLOTHROCRINIDAE Moore & Laudon, 1943

Genus ELIBATOCRINUS Moore, 1940

ELIBATOCRINUS sp.

Figure 4,6

Remarks.—A single crown is too disturbed in preservation to attempt a specific determination. The single infrabasal observed is quite large, doubtlessly representing two fused plates, which is characteristic of *Elibatocrinus*. Basals are large, thin plates. Proximal brachials are medially constricted and somewhat elongated. Primibrach *1* is axillary in observed rays. Distalward the secundibrachs are slightly elongated, cuneate, with well-rounded exteriors. Proximal columnals are thin, round.

Hypotype.—SUI 36904, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center SW ¼ NE ¼ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

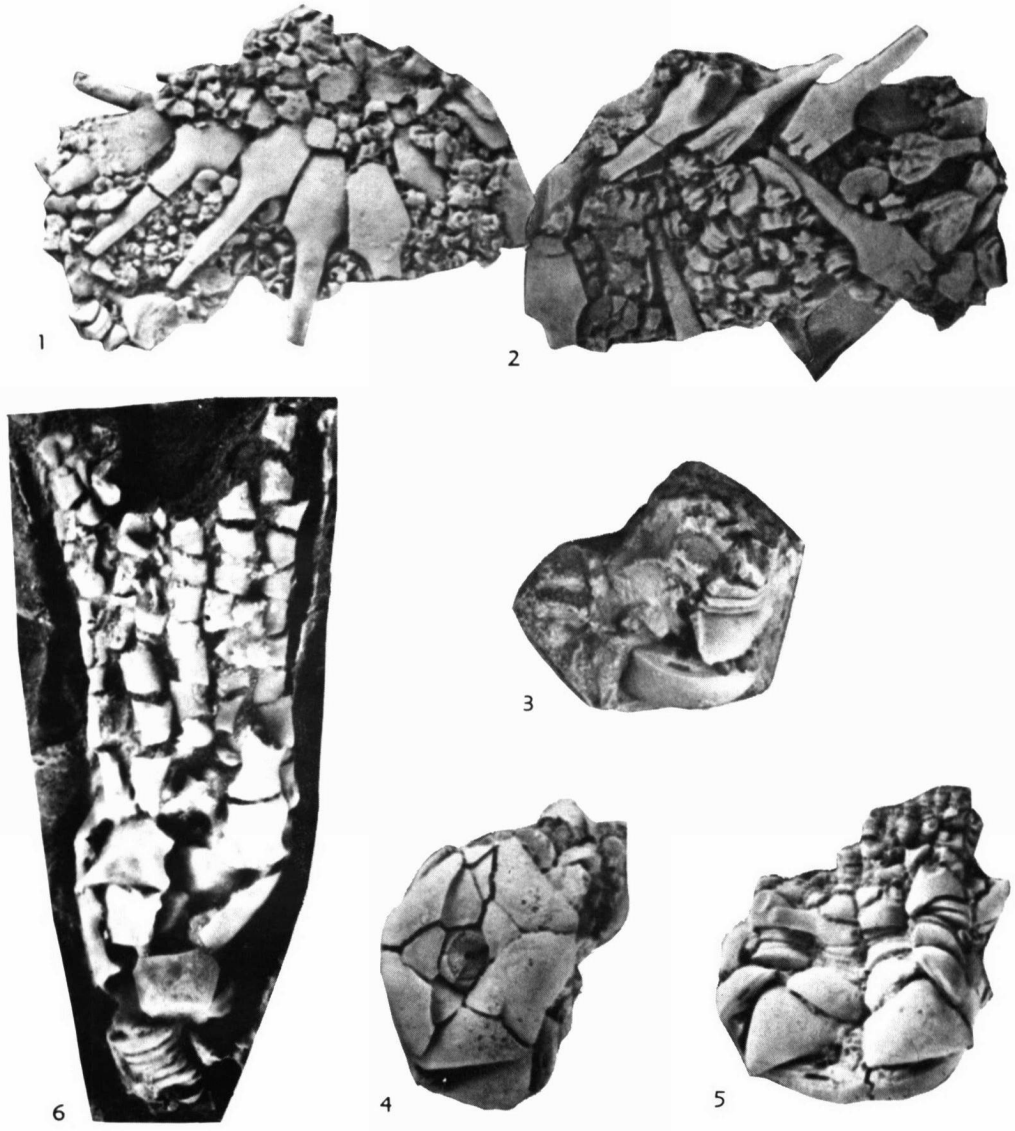

FIG. 4. *Anchicrinus* (1-5) and *Elibatocrinus* (6) from Atoka Formation, Oklahoma.——*1-5. A. echinosacculus* Strimple, n. sp., holotype crown (OU 7130); summit of anal sac terminating platform, under side of same, cup with attached lower brachials from anterior, base, and *BC* interray, ×1.5.——*6. E.* sp., hypotype (SUI 36904); side view of poorly preserved crown with attached proximal columnals, ×2.8.

Superfamily LOPHOCRINACEA Bather, 1899

Family LAUDONOCRINIDAE Moore & Strimple, 1973

Genus ANCHICRINUS Strimple & Watkins, 1969

ANCHICRINUS ECHINOSACCULUS Strimple, new species

Figure 4,*1-5*

Description.—Dorsal cup shallow, saucer-shaped, with wide, shallow basal concavity. Infrabasals five, subhorizontal, mostly covered by proximal columnal; basals five, rather narrow with distal ends visible in side view of cup; radials large, proximal ends extending into basal plane. Anal plates three in cup, in normal (primitive) arrangement; sac plates above are large (see Fig. 4,2). Arms uniserial, branchng isotomously with axillary primibrach *1* and again with secundibrach *5-6*; primibrach *1* is large and tumid but does not develop a spine; axillary secundibrachs are spinose. Evidence of a platform-like termination of the anal sac is afforded by disarticulated small plates and large spinose plates. The spinose plates have long, adjacent sides expanding away from attachment facets, thereafter constricting sharply and then extending as long slender spines. Ten platform spines have been observed in the specimen studied. Proximal columnal is round, crenulated about the perimeter and pierced by a small round lumen.

Discussion.—Anchicrinus echinosacculus is atypical of the genus as represented by the type species, *A. toddi* Strimple & Watkins, 1969, in lacking depressions at the angles of the cup plates and in having 10 or more spinose platform plates. There are eight outwardly directed spine-plates surrounding the platform at the summit of the anal sac. Some paratypes of *A. toddi* do not always show the depressions at angles of cup plates.

Types.—Holotype OU 7130, paratypes OU 7143, 7144, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham and H. L. Strimple.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center SW ¼ NE ¼ sec. 28, T. 1 S., R. 8 E., Coal County, Oklahoma.

ANCHICRINUS sp. A

Figure 5,*1,2*

Description.—The specimen considered here is an abnormal form in which only four infrabasals and four basals were formed, but five radials are present. The cup shape is affected in that distalmost tips of infrabasals may be visible in side view of cup and the cup is higher than normal for the genus. *A* radial is not in exact anterior position and one basal is in contact with *C, D* and *E* radials. There are depressions at the plate angles and three anal plates in normal (primitive) position except that radianal has lost contact with *DE* (abnormal) basal.

Hypotype.—USNM 144993, National Museum of Natural History, Washington, D.C.; collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); mine dump, SE ¼ sec. 20, T. 28 N., R. 32 W., 1.5 miles south of Centerville, Jasper County, Missouri.

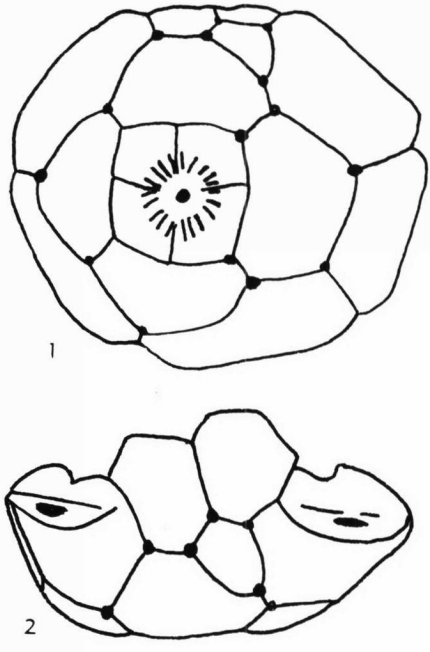

FIG. 5. *Anchicrinus* sp. A, hypotype (USNM 144993) from Burgner Formation, Missouri.——*1, 2.* Abnormal cup with infrabasal circlet and basal circlet reduced to four plates per circlet; radial circlet and posterior interradius normal with five and three plates, respectively, ×6.

ANCHICRINUS sp. B

Figure 6,7-9

Description.—Several disarticulated axillary primibrachs *1* in the Palmer collections from the Burgner Formation are virtually identical to similar elements of *Anchicrinus echinosacculus* from the Barnett Hill Member, Atoka Formation. A dorsal cup of *Anchicrinus* sp. B is reported herein from the Burgner Formation, but is abnormal and therefore not identifiable to species.

Measurements of Figured Specimens in Millimeters.—Length of primibrach *1* 9.0, width 14.6, height 6.7; height of proximal articular facet 5.9, width 14.5; length of upper facets 7.4, width 13.6.

Hypotype.—UM 14823B, Geology Department, The University of Missouri, Columbia, Missouri; collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); Wilson's Coal Bank, SE ¼ sec. 12, T. 28 N., R. 33 W., near Webb City, Jasper County, Missouri.

Family STELLAROCRINIDAE Strimple, 1961

Genus BRABEOCRINUS Strimple & Moore, 1971

BRABEOCRINUS PRIMUS Strimple, new species

Figure 7,*1,2*

Description.—Dorsal cup bowl-shaped with erect lateral sides and shallow basal concavity. Infrabasals obscured in preservation; distal ends of basals extend into lateral walls of cup, radials dominant cup elements. Radial and basal circlets bear stout plications or ridges, two on each radial which pass onto basals. Anals three, radianal elongated, resting obliquely across the distal face of *CD* basal and lacking contact with *BC* basal, supporting moderately large anal *X* above. *RX* notches into cup resting on left distal shoulder of *C* radial and right shoulder of anal *X*, well removed from contact with radianal. Arms ten (as preserved) cuneate, bordering on biserial, narrow and pinnulate with well-rounded exteriors. Primaxils have short lateral sides and a sharp median ridge with secundibrachs *1* directed outward and slightly upward. Subsequent brachials are staggered in appearance with pinnular-bearing side elongated and opposite side reduced to an apex.

Discussion.—*Brabeocrinus primus* is the oldest known species of *Brabeocrinus* and is probably the progenitor of *Stellarocrinus* in having an elongated radianal resting obliquely on the posterior (*CD*) basal.

Types.—Holotype OU 7131, paratype OU 7141, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center SW ¼ NE ¼ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily AGASSIZOCRINACEA S. A. Miller, 1890

Family ANOBASICRINIDAE Strimple, 1961

Genus ANOBASICRINUS Strimple, 1961

ANOBASICRINUS ? sp.

Figure 8,*1-4*

Description.—A group of arms lacking associated cup plates is considered here because the arms appear to belong to the family Anobasicrinidae and are hyperpinnulated (four pinnules for each brachial). Assignment to *Anobasicrinus* is questionable under the circumstances and is suggested because the genus is known from the Morrowan Stage through *A. obscurus* Strimple, 1961a, which also has somewhat similar arms, as far as preserved. The arms are composed of well-rounded brachials with multiple pinnules (two on each side of a brachial), which are situated on the inner side of the brachials. Several branchings are indicated.

Discussion.—*Neozeacrinus peramplus* Wanner, 1937, from the Permian of the Island of Timor has hyperpinnulation of the arms (four pinnules to a brachial); however, the arms are closely abutting and in fact are interlocking, whereas the arms of the present form do not abut. The structure of the crown of *N. peramplus,* i.e., rapid widening of the crown to midheight, and narrowing rapidly thereafter, suggests the presence of a large balloon-like anal sac.

Synyphocrinus cornutus Trautschold, 1881, is demonstrated by Yakovlev and Ivanov (1956, pl. 2, fig. 2a) to be hyperpinnulated, with two pinnules on one side and either one or two pinnules on the opposite side of one brachial. *Synyphocrinus* is considered to belong to the Anobasicrinidae (see Strimple & Moore, 1971a, p. 22).

Hypotype.—SUI 36329, group of associated arms, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka

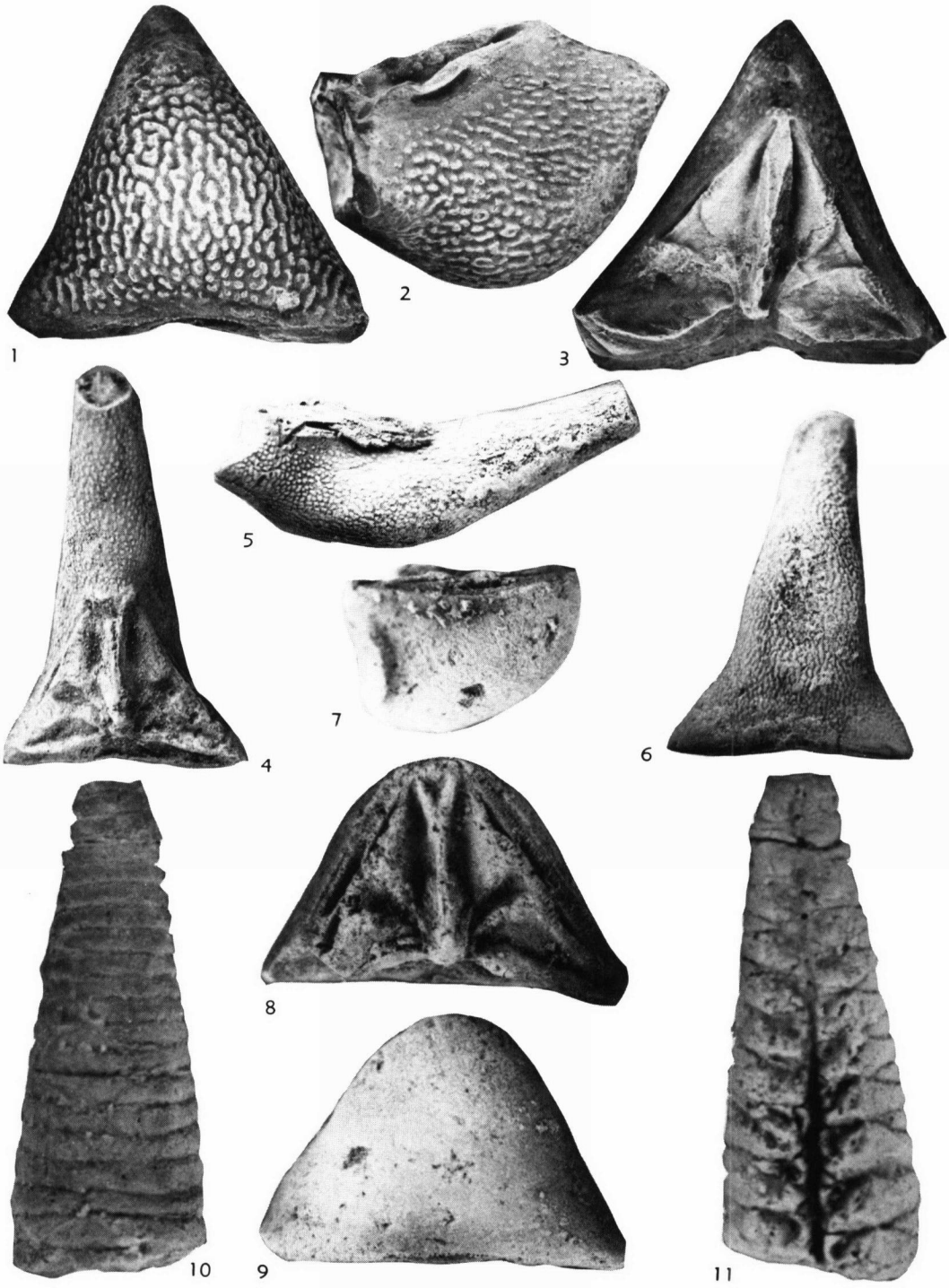

FIG. 6. *Affinocrinus* (primibrachs) *(1-6)*, *Anchicrinus* (primibrach) *(7-9)*, *Mooreocrinus* sp. (arm) *(10, 11)* from Oklahoma and Missouri. *(Continued on facing page.)*

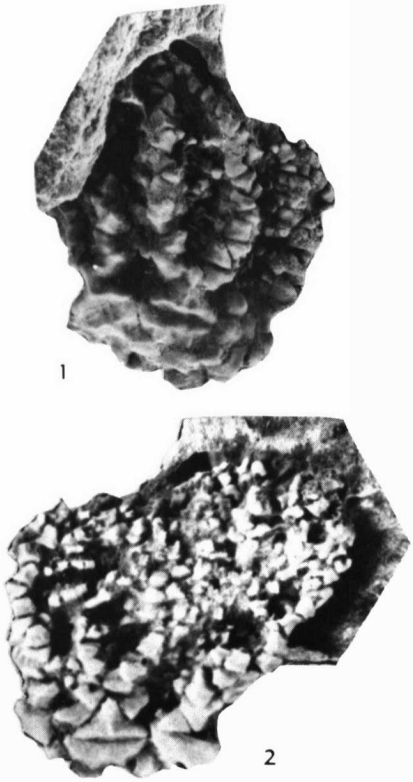

FIG. 7. *Brabeocrinus primus* Strimple, n. sp.——*1,2*. Holotype crown (OU 7131) from Coal County, Oklahoma, viewed from *D* ray (posterior interray to right), and *B* ray, ×2.8.

Formation, Atokan Stage (Middle Pennsylvanian); NE ¼ SW ¼ sec. 23, T. 1 N., R. 8 E., Coal County, Oklahoma.

Family AMPELOCRINIDAE Kirk, 1942

Genus MOUNDOCRINUS Strimple, 1939

MOUNDOCRINUS COALENSIS Strimple, new species

Figure 9,*1-4*

Description.—Dorsal cup shallow, mildly flared, basal concavity with subhorizontal or slightly downflared infrabasals. Five infrabasals extend beyond columnar cicatrix; five basals large, mildly convex, *CD* basal is considerably wider and evenly truncated for reception of a moderate-sized anal plate, basals extend out of basal concavity; radials wider than long with proximal ends almost reaching the basal plane, articular facets short, outer ligament pit strongly developed; anal plate quadrangular, not extending above cup summit, faceted for one tube plate. Arms unknown. Proximal columnal subpentagonal with short crenulation marking the perimeter.

Surface of cup plates are smooth.

Measurements (Approximate) of Holotype in Millimeters.—Height of dorsal cup 5.0, width 22.0; length of basal 8.5, width (normal) 6.5, width of *CD* basal 8.2; length of radial 6.2, width 12.0; length of anal plate 5.0, width 4.8.

Species is named for Coal County, Oklahoma.

Remarks.—*Moundocrinus coalensis* has a shallower cup than *M. osagensis* Strimple, 1939, type species for the genus.

Types.—Holotype OU 6075A, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); NE ¼ SW ¼ sec. 23, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily CROMYOCRINACEA Bather, 1890

Family CROMYOCRINIDAE Bather, 1890

Genus PARACROMYOCRINUS Strimple, 1966

PARACROMYOCRINUS PLANATUS Strimple, new species

Figures 8,*5*; 9,*5,6*

Description.—Holotype is a nearly complete crown, but, like much of the material recovered, the dorsal cup is crushed and disarticulated. All essential characters are evident. Curvature of the proximal ends of large basals indicates a slight basal concavity in the dorsal cup. Radials wide; a low, broad ridge is formed just below cup summit. Radianal rather slender, elongate, and quadrangular. Anal *X* missing, but distal end of posterior (*CD*) basal is truncated for reception of the element. Ten elongate arms bifurcate with primibrach *1*, which is almost as tall as wide and

1-3. *Affinocrinus* sp. B. Axillary primibrach *1*, OU 7137, from 100 ft. above Gene Autry Sh.; viewed from base, side, and summit, × 3.5.

4-6. *Affinocrinus* sp. A. Axillary primibrach *1*, SUI 37050, from Bostwick Fm.; viewed from summit, side, and base, ×3.

7-9. *Anchicrinus* sp. B. Axillary primibrach, *1*, UM 14823B, from Burgner Fm.; viewed from side, summit, and base, ×3.5.

10,11. *M.* sp. Distal portion of single arm, UM 14823C, from Burgner Fm.; viewed from exterior and interior, ×3.5.

FIG. 8. *Anobasicrinus (1-4)* and *Paracromyocrinus (5)* from Atoka Formation, Oklahoma.——*1-4. A.* sp.; *1, 2,* hypotype (SUI 36329), single arm removed from cluster of uniserial arms viewed from exterior and interior to show hyperpinnulation of some brachials; *3, 4,* cluster of arms from exterior and interior showing large, rounded pinnules with a faint keel, ×5.——*5. P. planatus,* n. sp. Paratype (OU 6077) termination of a set of biserial arms with closely packed, sharply keeled pinnules, ×5.

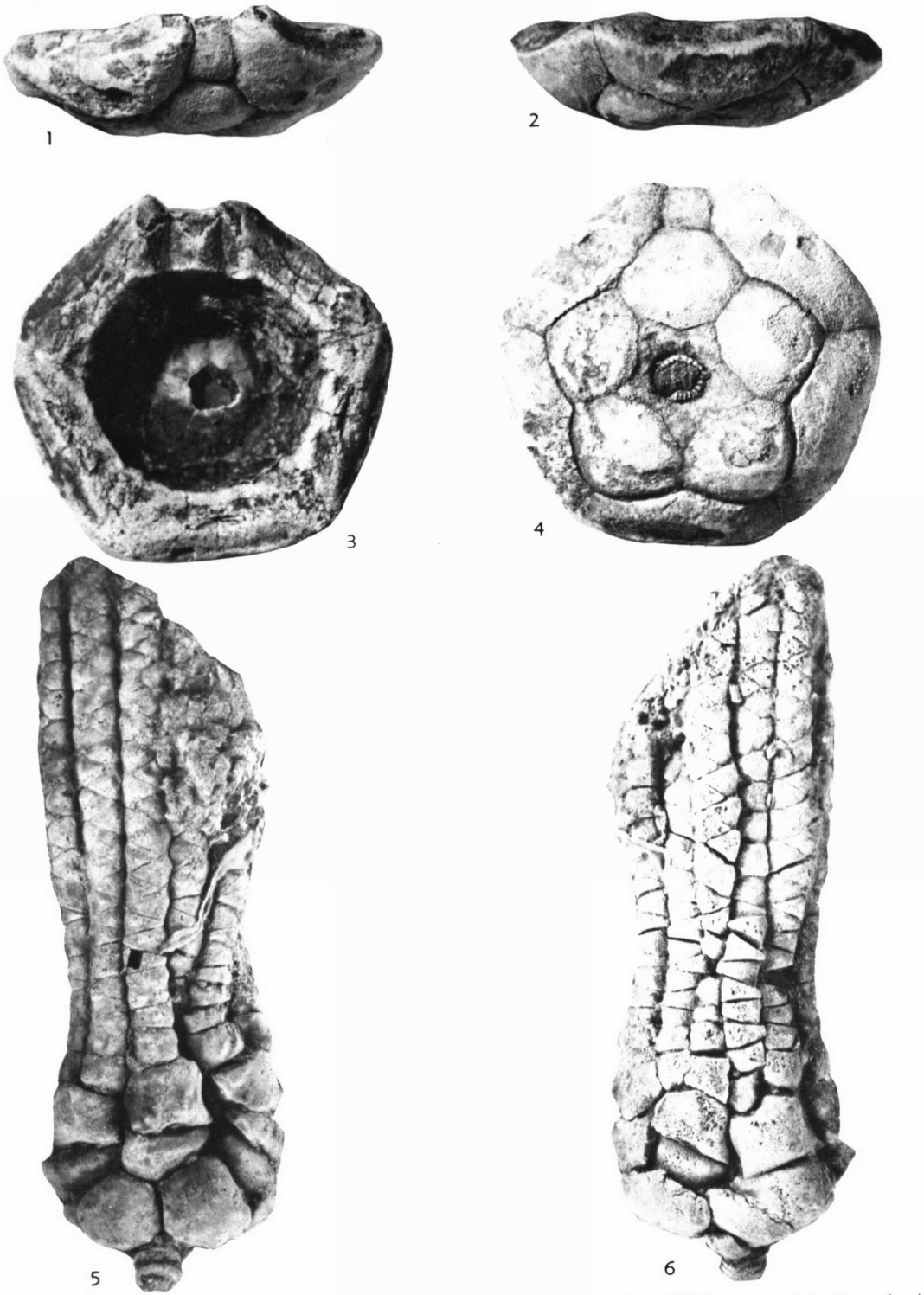

FIG. 9. *Moundocrinus (1-4)* and *Paracromyocrinus (5,6)* from Atoka Formation, Oklahoma.——*1-4. M. coalensis* Strimple, n. sp. Holotype (OU 6075A) cup from posterior, anterior, summit, and base, ×4.——*5,6. P. planatus* Strimple, n. sp. Holotype (OU 7129) crown from *D* ray and *AB* interray, ×1.6.

is tumid. Secundibrach *1* is rather large. Secundibrachs do not become biserial before the eighth segment. Low, horizontal ridges cause irregular appearance of lateral sides of the arms. Proximal columnals are alternatingly expanded, round.

Remarks.—The proximal portions of the arms of *Paracromyocrinus planatus* are uniserial (cuneate brachials) for a considerable distance (eight or nine secundibrachs). The holotype of *P. marquisi* has a large quadrangular secundibrach *1,* but thereafter they are smaller and wedge-shaped. The horizontally crested form of each arm segment is shared by hypotypes of *P. marquisi* from the Savanna Formation (Desmoinesian) of Oklahoma. In *P. planatus* there are low horizontal ridges on secundibrachs that are not crested. Dorsal cups of *P. marquisi* are ornamented by irregularly spaced pustules and are granular, whereas no such markings appear on *P. planatus*; instead, low swellings create an irregular surface. The cup and arms of *P. vetulus* (Lane, 1964), are smooth and the arms become biserial usually with secundibrach *3.* An early Pennsylvanian age was indicated by Lane (*ibid.,* p. 677) but a Chesterian age assignment was made later by Webster & Lane (1970, p. 277).

Types.—Holotype OU 7129, paratypes OU 6077, 7142, collected by Allen A. Graffham, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; SUI 36327 collected by H. L. Strimple, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ sec. 28 and NE ¼ SW ¼ sec. 23, T. 1 N., R. 8 E., Coal County, Oklahoma.

Genus MOOREOCRINUS Wright & Strimple, 1945

MOOREOCRINUS sp.

Figure *6,10,11*

Description.—The distal end of a single arm is tentatively assigned to the genus *Mooreocrinus.* It tapers rapidly and is uniserial; however, in side view the short side of a brachial does not reach the inner edge of the arm, which might indicate a transition toward a biserial state. Each brachial has a pinnular facet that alternates sides with adjacent brachials. Brachials are short with well-rounded exteriors.

Discussion.—Although *Cromyocrinus* has been reported from Morrowan rocks (Lower Pennsylvanian) of Oklahoma, there is no *bona fide* representative known. *C. simplex* Trautschold, 1867, type species of the genus, from Moscovian rocks (Middle Pennsylvanian) near Moscow, USSR, has only five arms. All cromyocrinids from North and South America have ten or more arms. For this reason the present species is considered to be *Mooreocrinus,* which has 10 uniserial arms.

Hypotype.—UM 14823C, Geology Department, The University of Missouri, Columbia, Missouri; collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); Wilson's Coal Bank, NE ¼ sec. 12, T. 28 N., R. 33 W., one-half mile northwest of Webb City, Jasper County, Missouri.

Genus METACROMYOCRINUS Strimple, 1961

METACROMYOCRINUS FUNDUNDUS (Strimple, 1966), new combination

Synarmocrinus fundundus Strimple, 1966a, p. 8-12, pl. 2, fig. 1-4.

Remarks.—This species is apparently derived from *Metacromyocrinus papulosus* (Moore & Plummer, 1938) of Morrowan age as illustrated by Moore & Strimple, 1973, pl. 10, fig. 1a-d. *M. fundundus* differs from *M. papulosus* in having reduced the size of the infrabasal circlet, in having sutures deeply impressed in V-shaped grooves, and the lateral sides of the cup are slightly more erect. Although *M. fundundus* has characteristics diverging from the primary lineage, i.e., the lineage retains wide, mildly upflared infrabasals, it is nevertheless considered here to be closely aligned with *Metacromyocrinus,* through *M. papulosus.* The exact nature of the base of the cup of *Synarmocrinus* Lane, 1964, is obscure because of poor preservation of known specimens but the arms are uniserial. The arms of *Metacromyocrinus* are typically biserial and are biserial in *M. gillumi* Strimple, 1966a, which is of Morrowan age. Some question exists as to the correct generic designations of some of the species and will probably not be resolved until more specimens are found with attached arms.

Metacromyocrinus fundundus (Strimple), new combination, is represented in the present collections by isolated cup plates. The holotype (SUI 12278) is from the Barnett Hill Member, Atoka Formation, Atokan, near center NW ¼ section 10, T. 1 S., R. 8 E., Coal County, Okla-

homa. A paratype (OU 4969) is from the same horizon exposed in center N ½ section 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Hypotype.—SUI 36297 (disarticulated plates), Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); SW ¼ section 23, T. 1 N., R. 8 E., and center N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily ERISOCRINACEA Wachsmuth & Springer, 1886

Family DIPHUICRINIDAE Strimple & Knapp, 1966

Genus DIPHUICRINUS Moore & Plummer, 1938

DIPHUICRINUS DOVELYENSIS Strimple & Moore, 1971

Figure 10,*1,2*

Diphuicrinus dovelyensis Strimple & Moore, 1971b, p. 5-6, fig. 1,*1*; 2,*7-10*; 3,*1-4*.

Remarks.—A single partial dorsal cup is assigned to *Diphuicrinus* without hesitation. The specimen is somewhat fragmentary for specific identification but is assigned with confidence to *Diphuicrinus dovelyensis*.

Hypotype.—SUI 36801, Geology Department Repository, The University of Iowa, Iowa City, Iowa, collected by H. L. Strimple.

Occurrence.—Webbers Falls Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); road cut at east end of bridge across Lake of the Cherokees, Oklahoma Highway 51, east of Wagoner, Wagoner County, Oklahoma.

Genus GRAFFHAMICRINUS Strimple, 1961

GRAFFHAMICRINUS ANTIQUUS Strimple & Watkins, 1969

Figure 10,*3-5*

Graffhamicrinus antiquus Strimple & Watkins, 1969, p. 182, pl. 30, fig. 14, 15; pl. 40, fig. 9, 10.

Remarks.—Two specimens of dorsal cups from the Bostwick Formation, Atokan of southern Oklahoma are in the material under study and are so similar to the holotype of *Graffhamicrinus antiquus* that assignment to the species is made without hesitation. The holotype of the species is from the Soldiers Hole Member, Big Saline Formation, Atokan Stage, Mason County, Texas. A poorly preserved specimen, designated as a paratype by Strimple & Watkins, 1969, is from the Marble Falls Formation (Morrowan), Espey Creek, Lampasas County, Texas.

Hypotypes.—OU 7126, OU 4748, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Bostwick Formation, Atokan Stage (Middle Pennsylvanian); road cut center North line, NE ¼ NE ¼ NE ¼ sec. 6, T. 6 S., R. 2 E., Love County, Oklahoma.

Family PROTENCRINIDAE Knapp, 1969

Genus PROTENCRINUS Jaekel, 1918

PROTENCRINUS ATOKA (Strimple, 1961)

Figure 10,*6,7*

Paradelocrinus atoka Strimple, 1961b, p. 228-229, pl. 1, fig. 1-3, 13-15.

Paradelocrinus atoka Strimple; Knapp, 1969, p. 353.

Description.—The species was originally described as *Paradelocrinus atoka* and was based on two dorsal cups, the holotype from the center N ½ section 28 and the paratype from SW ¼ section 23, both in T. 1 N., R. 8 E., Coal County, Oklahoma. Subsequently recovered material include cups and crowns of the species from both localities but most are from Section 23.

Ten long, slender, pinnulate, equibiserial arms branching on rather low primibrachs *1* in all rays. Exterior of arms gently convex with flat lateral sides so that arms are closely apposed when closed. Each brachial bears one pinnule. The arms make up 90 percent of the total length of the crown. The arms of *P. moscoviensis* Jaekel, type species of the genus, are incipiently biserial in distal portions.

In one specimen the lateral suture faces of a radial plate, which is part of a partial crown, is exposed and shows the surface is depressed with a thin, raised area about the rim (Fig. 10,*6*). There is an absence of the numerous nodes and ridges in the depressed areas which are found in *Delocrinus subhemisphericus* Moore & Plummer, 1940, as illustrated by Strimple & Moore (1971c, fig. 7,*3-7*).

Parasitic Attack.—The arms of one specimen (SUI 36800) are marked by numerous, round, shallow pits about 2.6 mm in diameter, which in some instances affect adjacent arms (Fig. 10,*7*). If an appreciable amount of time were involved

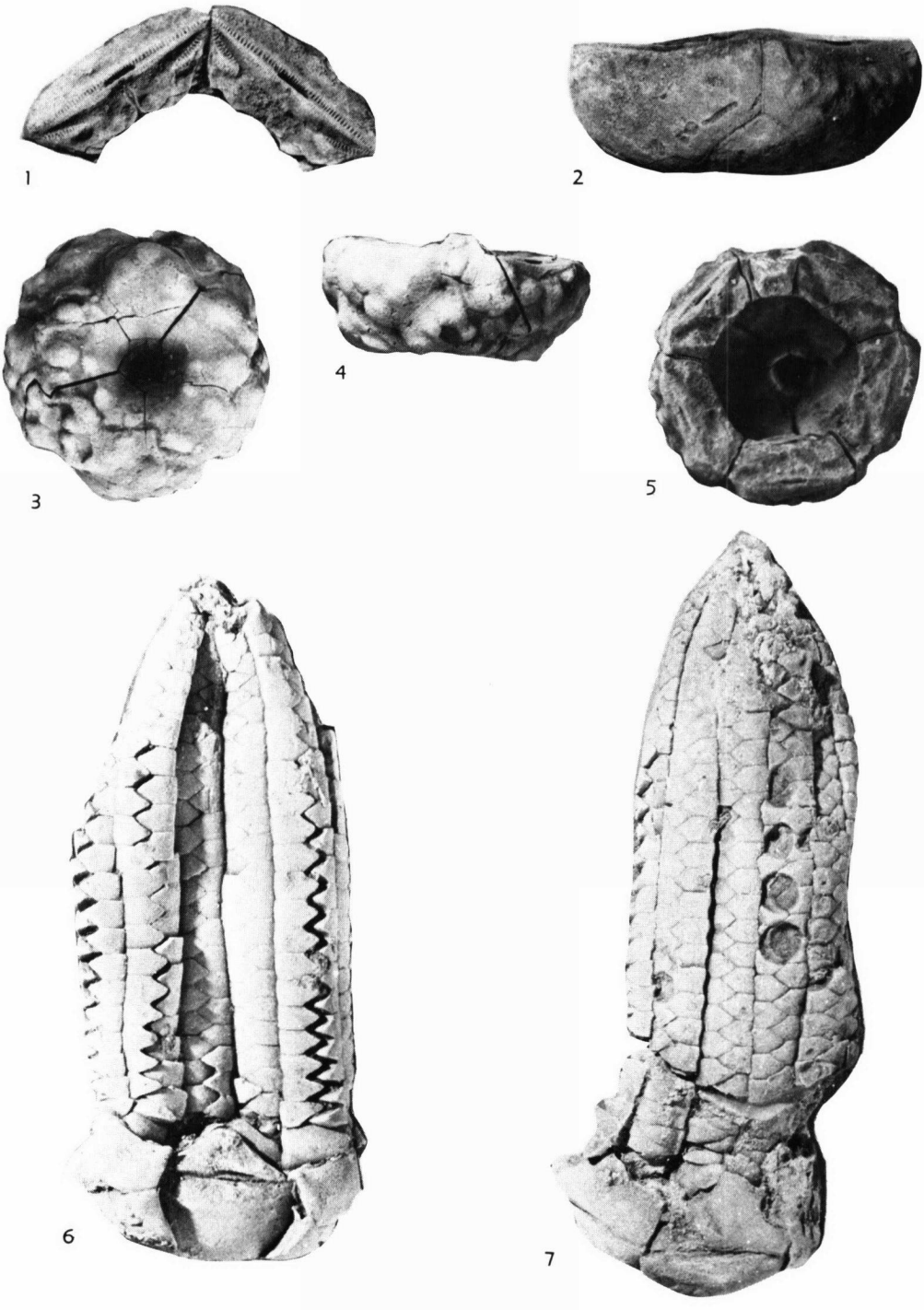

FIG. 10. *Diphuicrinus (1, 2)* and *Protencrinus (6, 7)* from the Atoka Formation, and *Graffhamicrinus (3-5)* from the Bostwick Formation, Oklahoma. *(Continued on facing page.)*

in cutting the pits, the crinoid would have utilized its ability to secret stereom locally, which it did not attempt. If the crinoid had been dead when the pits were made, it would have been on the ocean floor and therefore would have become at least partially disorganized. On the contrary, it is preserved as well as other specimens found in association. It thus appears that the crinoid was attacked while alive, probably by a carniverous gastropod, and closed its arms to protect its soft parts. Many crinoids are able to close their arms in such a manner to provide a completely sealed exterior, no doubt to protect their soft parts.

Types.—Figured hypotypes, SUI 37699, SUI 36800, SUI 36802, other hypotypes OU 4479, OU 5798, OU 6075B, OU 7149 (3 specimens); Paleontological Collections (OU), The University of Oklahoma, Norman, Oklahoma; Geology, Department Repository (SUI), The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); near center N ½ section 28, T. 1 N., R. 8 E. and SW ¼ section 23, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily DECADOCRINACEA Bather, 1890

[*nom. transl.* Strimple, herein (*ex* Decadocrinidae Bather, 1890)]

Families.—Decadocrinidae Bather, 1890 [=Ramulocrinidae Strimple & Watkins, 1969]; Clathrocrinidae Strimple & Moore, 1971a.

Diagnosis.—Cup low conical to bowl-shaped with convex, planate, to concave base; arms 10 equiuniserial to cuneate, stout pinnules or armlets, arm facets peneplenary or plenary; three anal plates, anal sac small, cylindrical.

Discussion.—This group of relatively small crinoids is first recognized in rocks of Devonian age. The arms branch on primibrach *2* and infrabasals are upflared in older genera, but the primibrachs apparently fuse and the base of the cup becomes flattened and develops a concavity in younger genera. Stout pinnules and three anal plates in the cup remain stable characteristics. Elongation of secundibrachs with staggered or zigzag pattern is culminated in the Clathrocrinidae where the arms together with arm-like pinnules form a latticework net.

Occurrence.—Upper Devonian-Upper Pennsylvanian; USA, USSR, Canada.

Family CLATHROCRINIDAE Strimple & Moore, 1971

Genus CLATHROCRINUS Strimple & Moore, 1971

CLATHROCRINUS GRILEYI Strimple, new species

Figure 11

Description.—Dorsal cup low, bowl-shaped, base invaginated; basals moderately large; radials wide, articular facets not filling distal face of plates, shallow, trough-like area below outer ligament area; two anal plates in cup, radianal resting obliquely on posterior basal, well removed from contact with *BC* basal, anal *X* resting in notch on left shoulder of radianal and right shoulder of *D* radianal, *RX* well above cup summit resting directly on short subhorizontal distal surface of radianal; arms 10, uniserial, primibrachs *1* axillary, elongated as are the secundibrachs, proximal ends expanded, distal ends both expanded and protruded, each secundibrach axillary and bearing an armlet on the opposite side from the main branch.

Measurements of Holotype in Millimeters.—Length of crown 23, width of cup 9.2, height of cup 4.5.

Remarks.—*Clathrocrinus grileyi* is similar to *C. clinatus* Strimple & Moore, the former having more protuberant distal ends of brachials. *C. grileyi* has a highly advanced anal plate arrangement. *C. clathratus* Strimple & Moore has a shallower, ornate cup.

Name.—Species named in honor of H. L. Griley, Miami, Florida.

Types.—Holotype, OU 7132, paratype OU 7133 (2 specimens), Paleontological Collections,

1,2. D. dovelyensis Strimple & Moore. Hypotype (SUI 36801) partial cup from Webbers Falls Member, Atoka Formation, Wagoner Co., Okla.; viewed from summit and side, ×2.5.

3-5. G. antiquus Strimple & Watkins. Hypotype (OU 7126) cup from Bostwick Formation, Love Co., Okla.; viewed from base, posterior, and summit, ×2.5.

6,7. P. atoka (Strimple). Hypotype SUI 36799 and 36800) crowns from Barnett Hill Member, Atoka Formation, Coal Co., Okla.; viewed from side, ×2. Note numerous pits from parasitic attack on SUI 36800.

FIG. 11. *Clathrocrinus grileyi,* n. sp., from the Barnett Hill Member, Atoka Formation, Coal County, Okla. Holotype crown OU 7132 viewed from posterior (*CD*) interray, ×7.5.

The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham: paratype SUI 36903, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); Coal County, Oklahoma; center N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily PIRASOCRINACEA Moore & Laudon, 1943

Family PIRASOCRINIDAE Moore & Laudon, 1943

Genus AFFINOCRINUS Knapp, 1969

AFFINOCRINUS ORBIS Strimple, new species

Figure 12,*1-4*

Description.—Dorsal cup low, bowl-shaped, covered by small granules, ellipisoid in outline when viewed from above or below, base sharply concave but infrabasals subhorizontal or very slightly downflared. Infrabasals five, mostly covered by columnar cicatrix; basals five, curving sharply out of basal concavity to form basal plane and extending well into lateral walls of cup; radials five, moderately large but not entering basal plane, curved inward at summit of cup, articular facets not directed outward to any pronounced degree and filling distal surface of radials, interradial notches wide except at perimeter of cup where they are closed, intermuscular notch prominent but muscle areas shallowly defined, transverse ridge thin but sharply defined, outer ligament furrow and pit thin. Anal plates three, in normal (primitive) arrangement, except for tendency of radianal to lose contact with *BC* basal. Arms unknown.

Discussion.—*Affinocrinus orbis* is distinguished from *A. concavus*, type species of the genus, in lacking pronounced transverse concavity in proximal portions of basals, in lacking interradial notches at summit of cup, and in possessing pronounced surface ornamentation. *A. abathus* Knapp, 1969, is atypical in having a very broad, shallow concavity and very shallow cup. It does have a faintly granular surface though not so pronounced as in *A. orbis*.

Types.—Holotype OU 7145, paratype OU 7134, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allan A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

AFFINOCRINUS sp. A

Figure 6,*4-6*

Description.—A distinctive primibrach *1* found in the Bostwick Conglomerate west of Ardmore, Oklahoma, has an ornamentation similar to *Affinocrinus orbis,* n. sp., from the Barnett Hill Member, Atoka Formation, of Coal County, Oklahoma, and is assigned to the genus with reservation. No portions of the arms of *Affinocrinus* are known so that affinity is only surmised. The primibrach is extended as a long spine, narrowing rather rapidly from the radial attachment area for a short distance (about half the length of the distal articular areas), tapering slowly toward its termination, which is not preserved. The distal articulating area is divided equally into two subtriangular areas by a ridge, which is itself divided by a very narrow slit. Each facet has an outer ligament furrow and pit, a transverse ridge, and two muscle areas, one of which is parallel to the wide end of the ossicle. The entire outer surfaces of the element, other than those with fossae, are covered by closely packed granules.

Figured Hypotype.—SUI 37050, collected by H. L. Strimple, reposited Geology Department Repository, The University of Iowa, Iowa City. Unfigured hypotypes OU 7135, 7136, collected by Allen Graffham, reposited Paleontological Collections, University of Oklahoma, Norman, Oklahoma.

Occurrence.—OU 7135, unnamed shale (Atokan) about 100 ft. above Gene Autry Shale (Morrowan); NW ¼ SW ¼ sec. 2, T. 4 S., R. 4 E., Johnston County, Oklahoma. OU 7136, unnamed shale (Atokan) above Otterville Limestone (Morrowan); center south line NE ¼ sec. 30, T. 3 S., R. 4 E., Johnston County, Oklahoma. SUI 37050, Bostwick Conglomerate, Lake Murray Formation, Atokan Stage, NW ¼ NW ¼ sec. 34, T. 4 S., R. 1 E., Carter County, Oklahoma.

AFFINOCRINUS sp. B

Figure 6,*1-3*

Remarks.—A slightly spinose axillary primibrach *1* from an unnamed shale (Atokan) about 100 ft. above the Gene Autry Shale (Morrowan) in Johnston County, Oklahoma, is very bulbous

in the lower proximal region. Assignment is made to *Affinocrinus* because of the rugose ornamentation.

Measurements of Figured Specimens in Millimeters.—Length 15.7, width 14.5, height 7.0; height of proximal facet 6.6, width 14.5; length of upper facets 9.3, width 14.1.

Figured Hypotype.—OU 7137, collected by Allen Graffham, Paleontological Collections, University of Oklahoma, Norman, Oklahoma.

Occurrence.—Unnamed shale (Atokan) 100 ft. above Gene Autry Shale (Morrowan) (Pennsylvanian); NW ¼ SW ¼ sec. 2, T. 4 S., R. 4 E., Johnston County, Oklahoma.

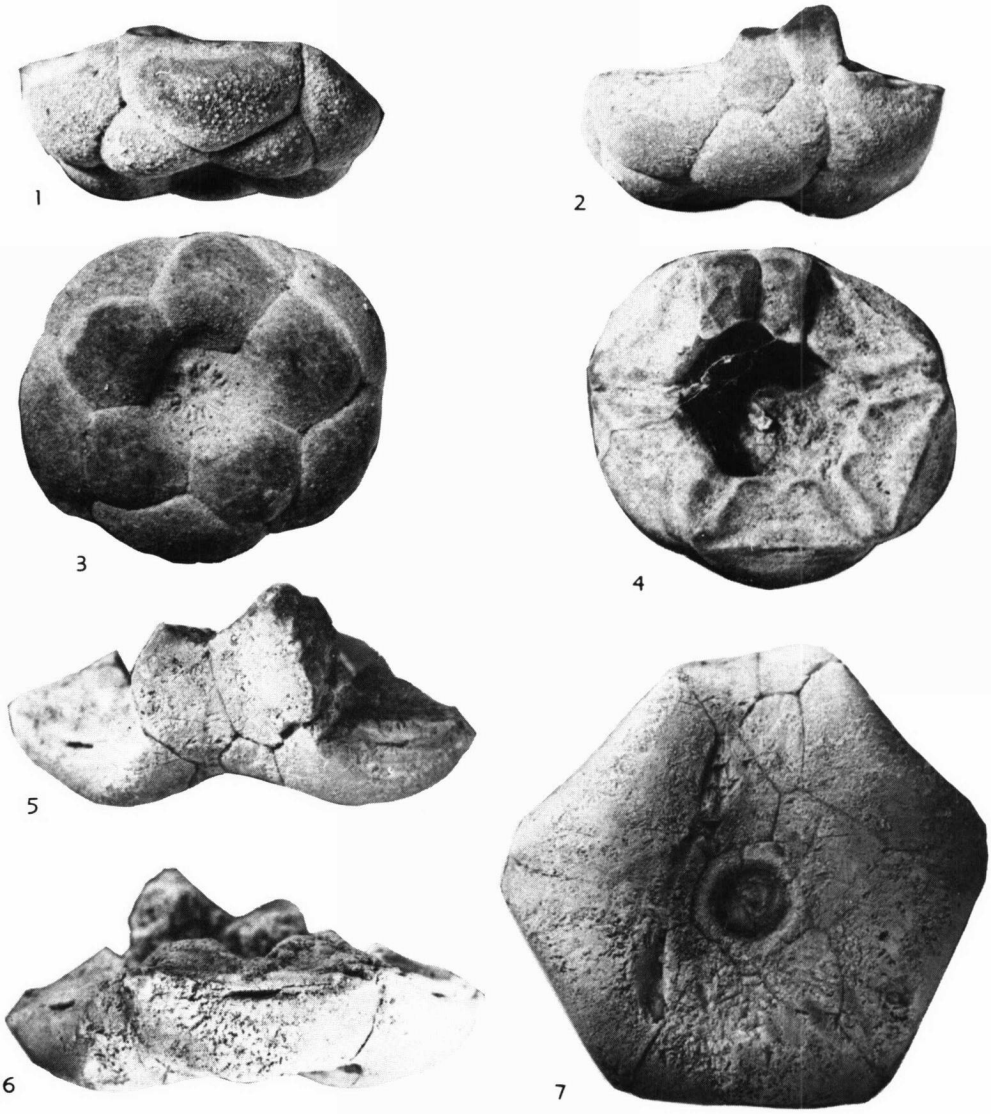

FIG. 12. *Affinocrinus (1-4)* and *Sciadiocrinus (5-7)* from Oklahoma and Missouri.——*1-4. A. orbis,* n. sp. Holotype cup, OU 7145, viewed from anterior, posterior, base, and summit, ×4.——*5-7. S. plautus,* n. sp. Holotype cup, USNM 144994, viewed from posterior, anterior, and base, ×2.5.

Genus PLATYFUNDOCRINUS Knapp, 1969

PLATYFUNDOCRINUS WEBBERSENSIS Strimple, new species

Figure 13,*1-3*

Description.—Dorsal cup very shallow, saucer-shaped with broad, shallow basal concavity. Infrabasal circlet small, subhorizontal, almost covered by denticulate columnar scar; basals narrow, elongate, with distal tips visible in side view of cup; radials dominant cup elements with proximal portions well into basal concavity and median portions bulged and directed downward; radial articular facets large, differentially weathered so as to apparently disclose pattern of growth, interradial notches present at cup summit, intermuscular notch large and V-shaped, outer ligament furrow is very thin and impressed area below the outer ligament furrow is restricted. The posterior side of the cup is not preserved.

Discussion.—Platyfundocrinus webbersensis differs from *P. typus* Knapp, 1969, type species of the genus, in having pronounced interradial notches, more slender, elongated basals, and in having bulbous radials. *P. webbersensis* demonstrates some characters of typical *Pirasocrinus,* i.e., subhorizontal infrabasals and bulbous radials, but has an altogether different cup form in being very shallow with the larger portion of the basals in subhorizontal position.

Holotype.—SUI 35597, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Webbers Falls Shale Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); road cut on Oklahoma State Highway 51, at east end of bridge crossing Lake of the Cherokees, east of Wagoner, Wagoner County, Oklahoma.

PLATYFUNDOCRINUS TYPUS Knapp, 1969

Figure 13,*4-6*

Platyfundocrinus typus Knapp, 1969, p. 371, text-fig. 2, 28; pl. 62, fig. 24-26.

Description.—Dorsal cup low, saucer-shaped, moderately deep basal concavity; infrabasals five, subhorizontal; basals five, essentially not visible in side view of cup; radials large, distal tips entering basal concavity. Anals three in cup, in normal (primitive) arrangement, radianal long and slender, anal *X* narrow at base but wide distalward, *RX* large. Column round, lumen pentalobate.

Discussion.—The genus and species are monotypic as presented by Knapp (1969, p. 370); therefore, the recording of a topotype of *P. typus,* type species of the genus, is considered to be desirable, especially for comparison with *P. webbersensis,* n. sp.

Topotype.—UM 14823A, Geology Department, University of Missouri, Columbia, Missouri; collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); Wilson's Coal Bank, sec. 12, T. 28 N., R. 32 W., 1 mile west of Webb City, Jasper County, Missouri.

Genus SCIADIOCRINUS Moore & Plummer, 1938

SCIADIOCRINUS PLANULATUS (Moore & Plummer, 1940)

Figure 14,*1,2*

Schistocrinus planulatus Moore & Plummer, 1940, p. 225-226, pl. 7, fig. 8.

Schistocrinus planulatus Strimple, 1961a, p. 100.

Description.—Crown tall cylindrical, extending above spinose termination of the anal sac. Dorsal cup shallow, bowl-shaped, imperfectly preserved. Radials are wider than long with proximal ends entering basal concavity.

Arms uniserial with well-rounded exteriors. Axillaries are short and devoid of projections. First branching with primibrach *1,* second bifurcation with secundibrach *1* or *2,* other bifurcations noted higher in the arms.

Umbrella-like termination of anal sac surrounded by at least ten outwardly directed, thick spines. The spines are different from most spines of this nature in that facets between spine plates are very short and tapering commences immediately at the end of the facets at a gentle angle. In stratigraphically younger species of the genus (and in related genera) there is usually a relatively long facet between spine plates so that the attachment area is rather long and widens appreciably before tapering starts, and usually the tapering is rather abrupt for a short distance.

Measurements of Hypotype Crown, OU 4478, in Millimeters.—Length of crown 39.5; height of cup *ca.* 4.5, width 16.0.

Discussion.—The spinose plates of the tegmen platform are different from those found in other species of the genus as previously explained. The holotype of *S. planulatus,* from the Millsap Lake Formation (Lower Desmoinesian), Parker Coun-

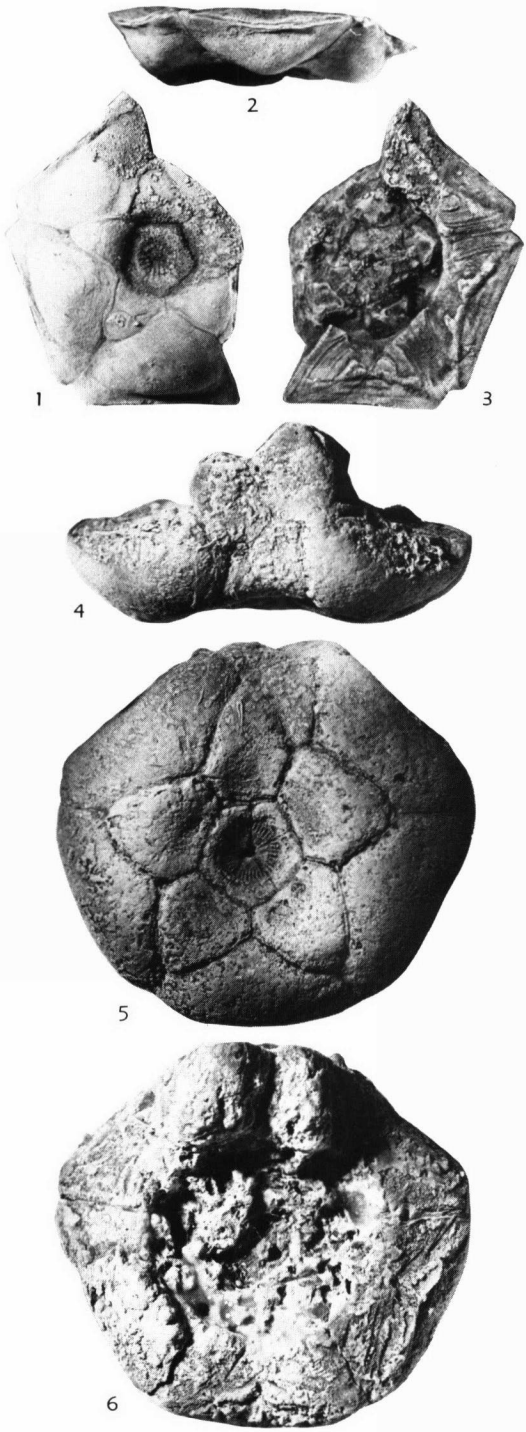

FIG. 13. *Platyfundocrinus* from Oklahoma and Missouri. ——*1-3. P. webbersensis,* n. sp. Holotype cup, SUI 35597, from Atoka Fm., Wagoner Co., Okla.; viewed from base, anterior, and summit, ×2.5.——*4-6. P. typus* Knapp. Hypotype cup, UM 14823A, from Burgner Fm., Jasper Co., Mo.; viewed from posterior, base, and summit, ×2.5.

ty, Texas, does not retain the platform-like anal sac termination.

Hypotype.—OU 4478, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); cen. N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

SCIADIOCRINUS PLAUTUS Strimple, new species

Figure 12,*5-7*

Description.—Dorsal cup very low, almost discoidal; granular surface, with a wide, gentle basal concavity encompassing all of the infrabasals, almost all of the basals and proximal ends of radials. Radials curve to a subvertical position to form lateral sides of cup. *A* radial has firm contact with *A* infrabasal. Interradial notches absent, and sutures not impressed. Radial articular facets sloping outward, transverse ridge prominent and expanding toward midportion of plate, outer ligament pit deep but not very long, a short forefacet present but indistinct. Posterior interradius is rather narrow within the cup but expands distalward where anal *X* and *RX* are prominent, large elements.

Measurements of Holotype in Millimeters.—Width of cup 24.6, height (exclusive of articular facets and anal plates) 4.6; width of basal concavity about 10.0, depth 1.2; width of infrabasal circlet 5.6, columnar impression 3.9; length of *DE* basal 4.4, width 4.7; length of *E* radial, along surface curvature to outer ligament pit, 9.6, width 13.2; length of radianal 6.1, width 3.0; length of anal *X* 7.3, width 4.3.

Discussion.—*Sciadiocrinus plautus* is apparently closely related to *S. llanoensis* Strimple & Watkins, 1969, from the Soldiers Hole Member, Big Saline Formation, Atokan Stage, Middle Pennsylvanian, near Mason, Mason County, Texas. *S. plautus* differs most obviously in having a juncture between *A* radial and *A* infrabasal, in possessing a depressed posterior interradius, and in lacking interradial notches. Sutures between radials are short but not eliminated in *S. llanoensis,* there is no pronounced depression in the posterior inter-

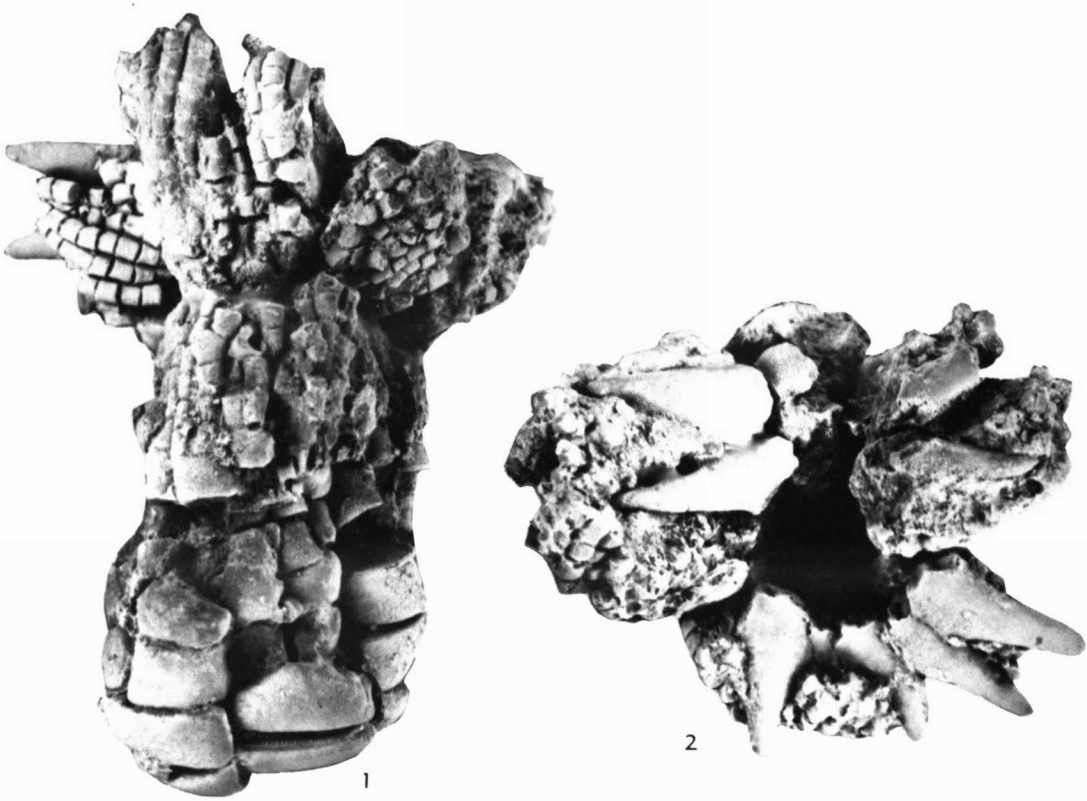

FIG. 14. *Sciadiocrinus planulatus* (Moore & Plummer) from Atoka Formation, Coal County, Oklahoma.——*1, 2.* Hypotype crown, OU 4478 side view and summit view showing spinose termination of anal sac, ×3.0.

radius, and there are decided interradial notches at the cup summit.

Holotype.—USNM 144994, National Museum Natural History, Washington, D.C., collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); mine dump, SE ¼ sec. 20, T. 28 N., R. 32 W., 1.5 miles south of Carterville, Jasper County, Missouri.

Superfamily TEXACRINACEA Strimple, 1961

Family CYMBIOCRINIDAE Strimple & Watkins, 1969

Genus OKLAHOMACRINUS Moore, 1939

OKLAHOMACRINUS FROSTAE Strimple & Watkins, 1969

Figures 1,3; 15,5

Oklahomacrinus frostae Strimple & Watkins, 1969, p. 194, pl. 34, fig. 1, 2.

Description.—Basal plates wide, convex though not tumid and restricted to a wide basal concavity; radial plates wide and long with proximal tips extending into basal concavity, outer ligament area large, transverse ridge prominent; anal *X* quadrangular-shaped, slightly longer than wide. Ten arms, slender, equiserial in external view, but in side view each nonpinnular-bearing brachial slightly reduced in height with adjacent pinnular-bearing brachial having a proportionately increased height. Primibrach *1* quadrangular, slightly narrower at summit than at base; primibrach *2* axillary, triangular-shaped, although there are in fact two very short lateral sides.

Discussion.—The large outer ligament area of a radial matched by a similar area in the proximal edge of primibrach *1* indicates the presence of a strong outer ligament and is usually reflected in preservation by outward directed arms. An exception is *O. frostae* in which the arms are directed upward, although they do not close tightly.

The holotype of *O. frostae* is from the Brannon Bridge Limestone Member, Millsap Lake Formation, Strawn Group, Desmoinesian, near Brock, Parker County, Texas. Specimens from Atokan rocks of Oklahoma are somewhat larger, but they show the tendency to direct the arms upward and are in other respects similar to the holotype.

Hypotypes.—OU 4480b, SUI 35073, SUI 36790, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma and Geology Department Repository, The University of Iowa, Iowa City, Iowa; collected by Allen A. Graffham and H. L. Strimple.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ section 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Genus PROALLOSOCRINUS Moore & Strimple, 1973

PROALLOSOCRINUS EXEMPTUS Strimple, new species

Figure 15,*1-4*

Description.—Dorsal cup low, bowl-shaped with broad basal concavity. Infrabasals, proximal portions of basals, basals, and proximal ends of radials in basal concavity with infrabasal circlet forming a subhorizontal or mildly downflared platform. Basals rather narrow and elongated, extending into lateral cup walls. Radials are the most distinguishing elements in having a pronounced curvature both laterally and longitudinally with pronounced proximal projection into basal region of cup. Anal plate quadrangular, rather narrow, followed by one tube plate. Primibrach *1* large and followed by axillary, triangular-shaped primibrach *2*; first secundibrach rather large, but thereafter the arms taper considerably before attaining a uniform width. Proximal columnals pentagonal.

Discussion.—Proallosocrinus exemptus appears to be a divergent trend in the lineage which, so far as known, ends with *Proallosocrinus annulatus* (Strimple & Watkins, 1969), new combination, from the Millsap Lake Formation (Desmoinesian) of Texas. The latter species was ascribed to *Aesiocrinus* with reservation by Strimple and Watkins (1969). In both species the cup is bowl-shaped with erect lateral sides and the radials are elongated with proximal portions entering a broad basal concavity. *P. annulatus* differs from *P. exemptus* in having a lower cup and in having a ridge parallel to the sutures in midsection of each secundibrach.

Proallosocrinus glenisteri Moore & Strimple, type species of the genus, differs from *P. exemptus* in having a more compact, erect dorsal cup in which the proximal ends of radials do not reach the basal plane, the basal concavity is more restricted, and arms are more robust.

Types.—Holotype OU 7127, figured paratype OU 5775, paratype (abnormal) OU 7128, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Family STAPHYLOCRINIDAE Moore & Strimple, 1973

Genus MICROCARACRINUS Strimple & Watkins, 1969

MICROCARACRINUS DELICATUS Strimple & Watkins, 1969

Figure 16,*3*

Microcaracrinus delicatus Strimple & Watkins, 1969, p. 201-202, pl. 44, fig. 12; pl. 46, fig. 1, 3, 4.

Description.—Small specimens under study do not appear to be distinguishable from *Microcaracrinus delicatus,* type species of the genus, from the Brannon Bridge Member, Millsap Lake Formation, Strawn Group, Desmoinesian Stage, Parker County, Texas.

The column is typically composed of alternatingly expanded columnals; however, paratype USNM S 5159, which has a considerable section of stem attached, demonstrates a thickening of columnals distalward and a reduction of the alternating nature of the segments. The Atokan hypotypes have more regular columnals, although there are a few alternatingly expanded segments in the proximal portion of stems.

Hypotype.—SUI 36904, Geology Department Repository, The University of Iowa, Iowa City, Iowa.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ sec. 28, T. 1 N., R. 8 E., Coal County, Oklahoma.

Superfamily ZEACRINITACEA Bassler & Moodey, 1943

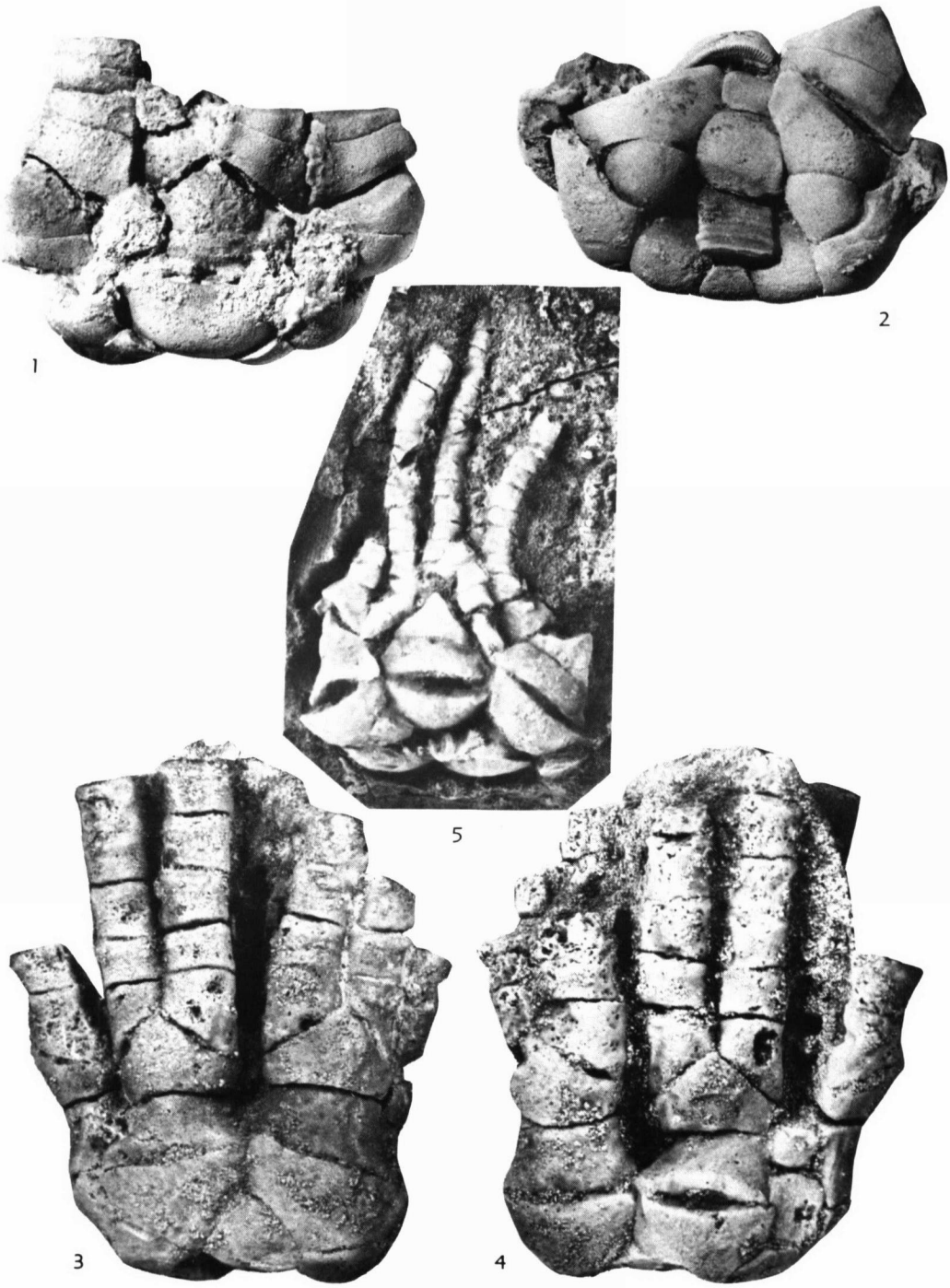

FIG. 15. *Proallosocrinus (1-4)* and *Oklahomacrinus (5)* from Atoka Formation, Coal County, Oklahoma.——*1-4. P. exemptus,* n. sp.; *1, 2,* paratype, OU 5775; from anterior and oblique posterior, ×1.7; *3, 4,* holotype crown, OU 7127; viewed from *AB* interray and *D* ray, ×5.——*5. O. frostae* Strimple & Watkins, hypotype crown, SUI 36790, in side view, ×2.4.

Family ZEACRINITIDAE Bassler & Moodey, 1943

Genus ALCIMOCRINUS Kirk, 1938

ALCIMOCRINUS GIRTYI (Springer, 1926)

Figure 16,*1,2*

Zeacrinus girtyi Springer, 1926, p. 83-84, text-fig. 3; pl. 23, fig. 9, 9a.
Alcimocrinus girtyi (Springer), Kirk, 1938, p. 163.

Description of Hypotype.—Dorsal cup, shallow bowl-shaped with broad, deep basal concavity. Five small infrabasals confined to bottom of concavity and almost covered by the large proximal columnals. Five basals in basal concavity, curving sharply out so that the distal portions form the basal plane and ends are visible in side view of cup. Five radials large with proximal ends entering into basal plane. An unusually even juncture occurs between radials and primibrachs. Three anal plates in normal (primitive) arrangement.

First branching of the arms takes place with

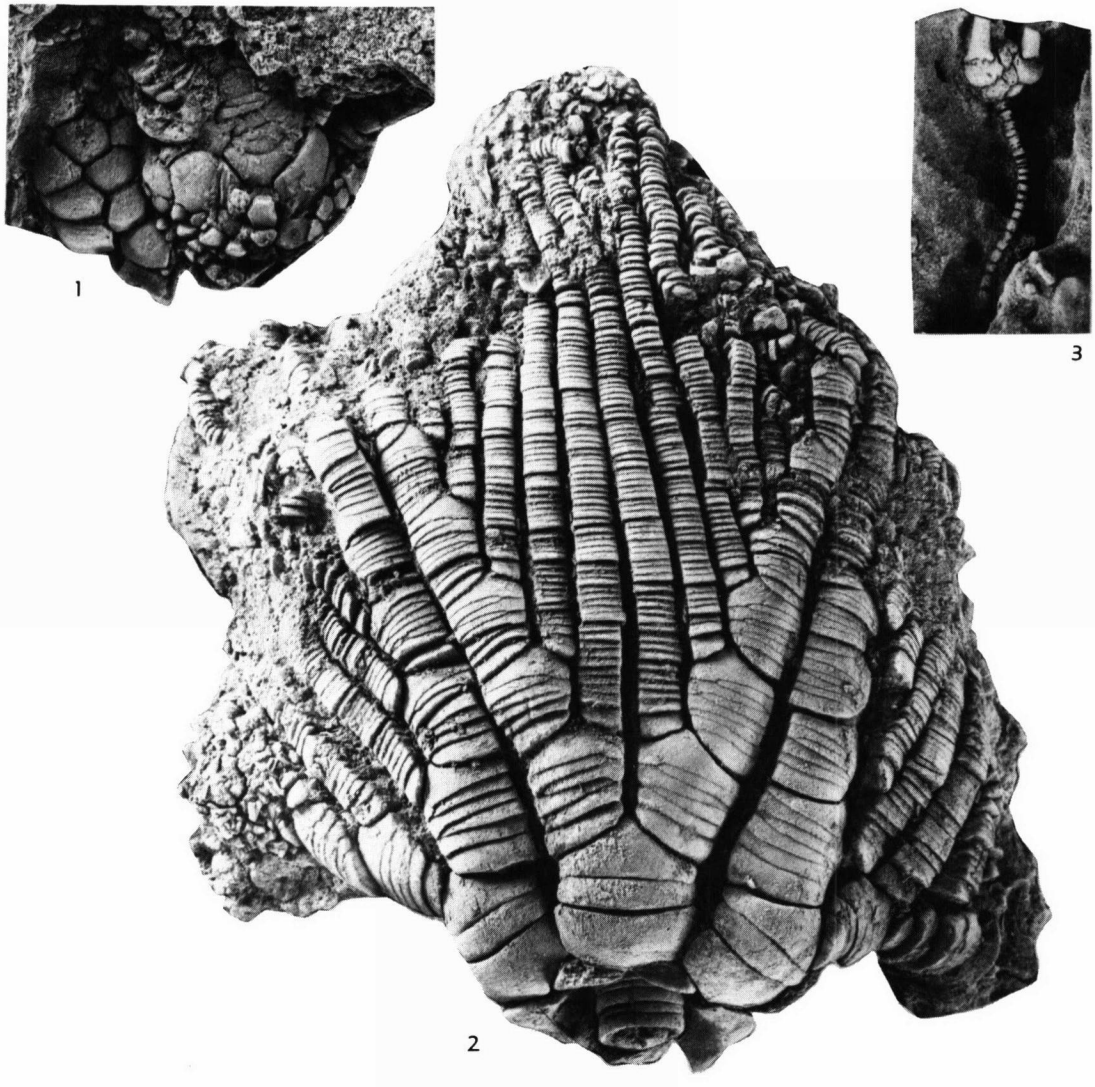

FIG. 16. *Alcimocrinus (1,2)* and *Microcarinocrinus (3)* from Atoka Formation, Coal County, Oklahoma.——*1,2. A. girtyi* (Springer), hypotype crown, OU 4481; cup in oblique posterior view to show anal plates, anterior view of crown, ×1.7.——*3. M. delicatus* Strimple & Watkins, hypotype, SUI 37904; posterior view, ×2.

the second primibrach in all arms and a second branching on or about the sixth secundibrach. Thereafter, arms are endotomous and may branch six or more times. As many as 80 arms may be formed. Brachials in the main arm trunks are wide, low segments, which widen in each group until the division takes place with a low axillary and are interlocking (inequiserial) above the second secundibrach. The smaller inner arms are uniserial for the entire length. The wide biserial main trunks and narrow uniserial inner arms create a distinctive appearance.

The lower portion of the tegmen is composed of large polygonal plates. Only proximal columnals of the stem are preserved. They are large, circular in outline, with sutures well defined, but not greatly impressed.

Measurements.—Crown 73.5 mm long as preserved; dorsal cup 26 mm wide and about 5.5 mm high.

Remarks.—Evolution of this lineage is now well documented. *Alcimocrinus ornatus* Strimple (1949) in the Fayetteville Formation has less numerous arms and the main trunks are not so differentiated from the inner arms. Typical *Alcimocrinus girtyi* (Springer) has as many arms but exhibits only a tendency toward interlocking brachials. The Atokan hypotype has more interlocking (inequiserial) brachials. No Desmoinesian or earlier representatives of the genus have been reported.

The type locality of *Alcimocrinus girtyi* is given by Springer (1926, p. 85) as "Morrow formation of the basal Pennsylvanian; near Crittenden in Northeastern Oklahoma." The village of Crittenden no longer exists, but, according to U.S.G.S. Folio 132 by Taff (1960), it was located in the north part of section 27, T. 17 N., R. 21 E., Cherokee County. The nearest Morrowan exposures known to me are about 1 mile to the southeast, about 2 miles to the northwest, or 2½ miles to the west. From personal observation it seems most likely that the material came from the southeast. In any event, there is also a specimen of *A. girtyi,* designated here as a hypotype, collected by L. R. Laudon at the abandoned Keough Quarry located in the SW corner section 25, T. 16 N., R. 19 E., Cherokee County, Oklahoma, from Morrowan rocks (probably Brentwood Member, Bloyd Formation). The specimen SUI no. 32315 is reposited in the Paleontological Collections, University of Iowa, Iowa City.

Hypotype.—OU 4481, Paleontological Collections, The University of Oklahoma, Norman, Oklahoma; collected by Allen A. Graffham.

Occurrence.—Barnett Hill Member, Atoka Formation, Atokan Stage (Middle Pennsylvanian); center N ½ section 28, T. 1 N., R. 8 E., northwest of Clarita, Coal County, Oklahoma.

Subclass CAMERATA Wachsmuth & Springer, 1885

Order MONOBATHRIDA Moore & Laudon, 1943

Superfamily HEXACRINITACEA Bassler, 1938

Family ACROCRINIDAE Wachsmuth & Springer, 1885

Subfamily ACROCRININAE Wachsmuth & Springer, 1885

Genus PLANACROCRINUS Moore & Strimple, 1969

PLANACROCRINUS KNAPPI Strimple, new species

Figure 17,*1-8*

Description.—Calyx moderately tall, truncate cone-shaped. Basal circlet composed of two large plates, divided by anteroposterior suture and subhorizontal except for distal ends, which curve sharply upward in line with higher sides of calyx. Radials wider than high, articular facets filling width of plates with a transverse ridge, two muscle fields, and shallow ligament fossae. Primanal (*X*) hexagonal in outline with greatest width below midheight; does not reach summit of the calyx. Directly beneath primanal in series are three subanal intercalaries. Three subradial intercalaries in series beneath the *A* radial. Distal intercalaries in the four other rays, excepting those directly below *A* radial, all interradial in position. In the holotype, the distalmost intercalary between *D* and *E* radials failed to develop for which compensation is made by extension of the lower left side of *D* radial, extension of the intercalary between *A* and *E* radials, and to a lesser degree extension of the right side of *E* radial. Above the calyx the primanal is followed in series by four plates terminating at the anal opening. In the other four interrays, narrow pillar-like plates support a dome apparently composed of five large

oral plates, one of which (posterior) is almost obliterated by the anal opening. Sutures are obliterated.

A set of arms found at the same exposure is assigned to the species because the arms are like those found in a crown of an undescribed species of the genus in Missourian rocks of Kansas. The arms are equibiserial with almost planate exteriors and lateral sides, much like those of some inadunate forms (e.g., *Erisocrinus*).

Columnar attachment cicatrix is obscured. Calyx (including tegmen) 7.3 mm high, 5.3 mm high to summit of radials, 5.2 mm maximum width.

Discussion.—When compared with *Planacrocrinus ambix* Moore & Strimple, 1969, the calyx

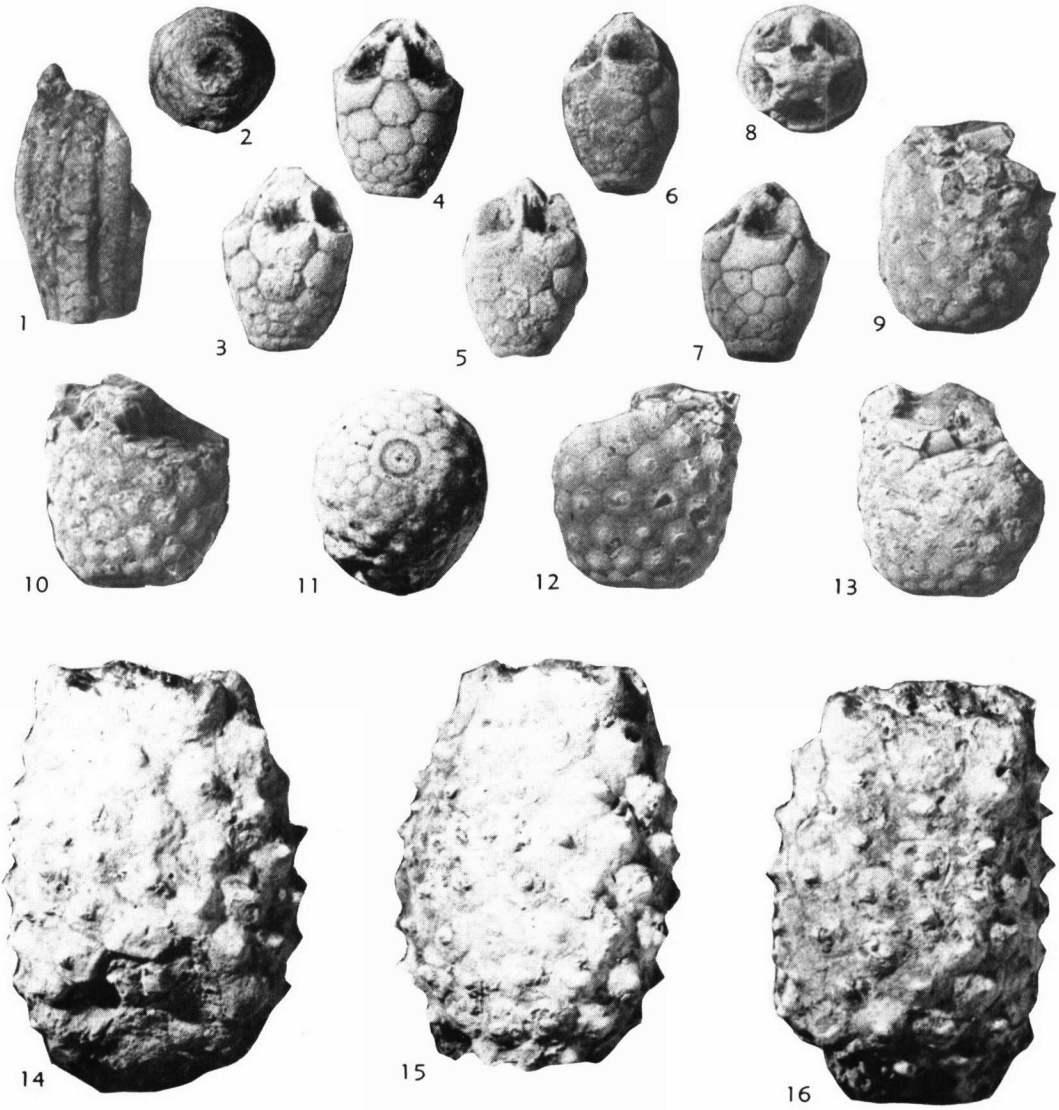

FIG. 17. *Planacrocrinus (1-8)* and *Globacrocrinus (9-16)* from the Burgner Formation of Missouri.——*1-8. P. knappi* Strimple, n. sp.; *1,* paratype (UM 14825b) arms; *2-8,* holotype theca (UM 14825), base, anterior, posterior, *AB* interray, *AE* interray, *C* ray, summit, ×3.——*9-16. G. centronodus* Strimple, n. sp.; *9-13,* paratype cup (USNM 144999a) from *A* ray, *E* ray, base, *B* ray, *D* ray; *14-16,* holotype cup (USNM 144999) from *AE* interray, *BE* interray, *CD* interray, ×3.

of *P. knappi* is cone-shaped and the former is more bowl-shaped. *P. conicus* Moore & Strimple, 1969, is cone-shaped, but the calyx is taller, primanal extends above the distal edge of radials, and there are five intercalaries in series below the primanal. *P. conicus* is a very small specimen so that the difference in the number of circlets of intercalaries (three in *P. knappi* but five in *P. conicus*) is not a matter of age differential. *P. minutus* Moore & Strimple, 1969, may be a juvenile of *P. ambix* and, if so, ontogenetic change would be from a high calyx to a lower, more bowl-shaped calyx. The oral plates of *P. minutus* rest on and are only slightly larger than the suborals and the posterior plates do not appear to be differentiated from the other four interrays. The orals form an apex quite different from the cap-like arrangement found in *A. knappi*.

The species is named for W. D. Knapp who researched the specimens while a Ph.D. candidate at The University of Iowa.

Types.—Holotype UM 14825, partial cup, paratype UM 14825a, hypotype (arms) UM 14825b, in the Geology Department, University of Missouri, Columbia, Missouri, collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian).

Subfamily GLOBACROCRININAE Moore & Strimple, 1969

Genus GLOBACROCRINUS Moore & Strimple, 1969

GLOBACROCRINUS CENTRONODUS Strimple, new species

Figure 17,9-16

Description.—Calyx moderately large, globose, with greatest diameter at about midheight above broad, planate base. Plates slightly tumid with a node in midsection of each plate. Primanal (*X*) in line with and almost as large as radials, hexagonal with broad distal facet. Directly below primanal are four subanal intercalaries in series, with the series interrupted by juncture of side intercalaries, and one more subanal below. The base of the holotype, on which the above observations are based, is absent but in two paratypes at least one more interruption of the continuous series has been observed and in one, two interruptions occur before basal plates are reached. The same condition exists in the *A* ray where four subradial intercalaries are in series, with the series interrupted and followed below by another subradial intercalary. Radials pentagonal except for *A* ray in which the proximal end is truncated and followed directly below by a subradial intercalary. Radial articular facets arcuate with substantially less width than distal width of radials. Columnar cicatrix round, crenulate, surrounding a broad, smooth area with small, round lumen in the center.

The holotype is 17.4 mm tall, maximum width 12.5 mm, width at summit 8.8 mm.

Discussion.—*Globacrocrinus centronodus* appears to be closely related to *G. pirum* (Moore & Plummer), which species, however, has a pear-shaped calyx; that is, the base is broader. *G. centronodus* has more of a barrel shape and is distinguished from all other acrocrinids in having a single node on each calyx plate.

Types.—Holotype USNM 144999, paratypes USNM 144999a, 144999b, National Museum of Natural History, Washington, D.C., and Geology Department, University of Missouri, collected by the late E. J. Palmer.

Occurrence.—Burgner Formation, Atokan Stage (Middle Pennsylvanian); mine dump SE ¼ sec. 20, T. 28 N., R. 32 W., 1.5 miles south of Carterville; paratypes, Wilson's Coal Bank, NW ¼ sec. 12, T. 28 N., R. 32 W., 1 mile west of Webb City, Jasper County, Missouri.

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ERRATUM

LOWER PENNSYLVANIAN (MORROWAN) CRINOIDS FROM ARKANSAS, OKLAHOMA, AND TEXAS

Paleontological Contributions ARTICLE 60, 1973

In a recent study of Morrowan crinoids by Moore & Strimple (1973), the holotype of *Diphuicrinus mammifer* was listed in the text (p. 65) as being OU 233. The University of Oklahoma Paleontological Collection catalogue number OU 233 is applicable to three specimens of *Allocatillocrinus morrowensis* (Strimple), which are also from the lower part of the Wapanucka Formation in Pontotoc County, Oklahoma. The holotype of *Diphuicrinus mammifer* is reposited at The University of Iowa, Geology Department Repository, SUI 11902, and is figured by Moore & Strimple (*ibid.*, pl. 14, fig. *3a-d*), which specimen is listed by them in the text (*ibid.*, p. 65) and plate explanation (*ibid.*, p. 57) of plate 14, as a paratype of the species.